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Molded Electrical Insulation and Plastics

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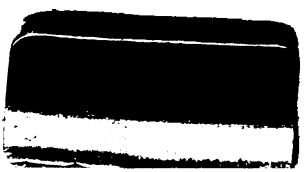

Molded Electrical Insulation and Plastics

By

EMILE HEMMING

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INTRODUCTION

About ten years ago a leading electrical concern in Europe sent one of its engineers on an extended trip to America for the purpose of studying and reporting the progress made in the field of molded insulation for electrical purposes.

Having had full access to the works of the large manufacturing concerns, and after careful study of conditions, the engineer returned home and reported that the state of the art in this field was about the same in both countries.

Since then a series of new inventions in the field of electrical insulation products have been developed and enormous progress has been made.

While electrical engineers have been kept somewhat informed of these new inventions and products through the medium of technical periodicals and advertisements, yet no book has been published dealing in an entire, comprehensive and unbiased manner with the developments in this art.

This subject of molded insulation is one of great and growing importance in almost every branch of electrical art. A few years ago the choice of insulating materials lay practically between porcelain, hard rubber. and the so-called shellac compounds, but to-day a considerable number of substances of widely different properties and constituents are offered on the market.

The purpose of this book, therefore, is to deal thoroughly and as briefly as possible with the progress in the field of molded insulation, to trace its development during the last ten years, and to discuss its present status; to treat of the important basic principles of the new products and inventions, omitting specific trade names; to give the engineer an insight into materials and methods employed in manufacture, disclosing various characteristics, both favorable and unfavorable; and so to guide him to a proper selection of the substances best suited to his wants and requirements.

I will try to explain in a short, practical way, how out of hundreds of new products which have appeared on the market, and for which great claims have been made by inventors and experimenters, only a few have stood up and survived under operating conditions; and how these have contributed to electrical progress.

Never before has the interest of the electrical engineer been so keen as to what type of insulating parts to use in his machine or apparatus as at present, and I, therefore, express the hope that this short treatise may be a helpful guide and of particular interest to him.

EMILE HEMMING.

Passaic, N. J., U. S. A.
April, 1914.

WHAT IS MOLDED INSULATION?

The term "Molded Insulation" is applied to that class of mechanical elements of electrical apparatus used for insulating purposes. These elements are formed of a plastic mass in molds or dies, usually under pressure.

This plastic mass is composed fundamentally of two elements, viz: a binder, and a filler. Both organic and inorganic binders and fillers are used.

When the binder is organic the mixture depends upon it principally for its insulating qualities, and the filler, while it may have an insulating value, is used either to make the mixture cheaper or because of its mechanical or physical properties.

Inorganic binders are used primarily to produce materials capable of withstanding greater heat than the organic; they sometimes not only act in the capacity of a binder, but enter into combinations of a mechanical or chemical nature with the fillers.

In the early days, makers of electrical apparatus used for insulating purposes such materials as were found at hand. Of these slate, marble, wood and mica were found to be best suited for the respective purposes. The demand for a material which could be more readily shaped into complicated forms soon added porcelain, hard rubber and fibre to the list.

These three manufactured products were early adopted as standards. Their properties are well known and the characteristics of the output of the various

makers differ from each other in only a comparatively slight degree.

The progress made in the construction of electrical machinery and appliances very soon created a demand for other materials which would embody the desirable features of these substances and also possess qualities which they lacked. This demand has given being to a very diversified group of products which are classified under the title given this book.

All kinds of materials are commonly referred to under the general term of "COMPOSITION." Molded Insulation embraces a great variety of products differing widely in their characteristics as well as in their constituent elements; and because of the newness of this art and because of the secrecy maintained by the manufacturers, engineers are by no means as well informed of the nature of these products as they should be.

These newer materials are so rapidly coming into extensive use that it is highly important that they be properly classified and that their characteristics be thoroughly understood by electrical engineers and designers.

I will, therefore, try to classify into standard categories all the so-called molded compositions developed up to the present time, especially those which have been most generally adopted by electrical manufacturers.

MOLDED INSULATION TEN YEARS AGO

Ten years ago the molded insulating material most widely used was porcelain. It was practically the only fireproof material known at the time. Its high dielectric strength, when properly made, its waterproof qualities and its low cost made it indispensible for a great many uses.

Owing, however, to its brittleness, it was unsuitable for many purposes, and electrical engineers and constructors employed vulcanzied fibre or wood impregnated with oil to a considerable extent.

Hard rubber was also much used as an electrical insulator, either as such or as a binder in materials having asbestos or other mineral substances as fillers. These so-called vulcanized asbestos materials, composed of asbestos fibre with rubber as a binder, were molded into the required shapes and then vulcanized. They were excellent in every respect except price and the inability of rubber to withstand any considerable degree of heat.

In the writer's opinion these products constituted the best molded materials produced up to that time, but the steadily increasing price of rubber made the cost of articles of this material prohibitive for many purposes, and gave rise to many substitutes, some of which came into extensive use. I refer especially to the so-called shellac compounds, based principally on the use of shellac,

asphalt, rosin and other gums as binders for asbestos, or other fillers.

These shellac materials were all molded in heated dies and cooled before being removed therefrom as a finished product, which is a method of manufacture much cheaper and simpler than the somewhat lengthy process of vulcanization so necessary when rubber is employed and one of the chief reasons for the wide popularity of materials of this character.

Numerous attempts have been made in the last ten years to utilize **alkaline silicates** as binders for asbestos and other fillers. They make good binders, but on account of their inability to resist the softening influence of moisture, various processes were developed to render them insoluble. These depend on the use of lime compounds, aluminates, etc., and while it was found possible to convert the silica into an insoluble form, other products of reaction were always present, which were just as readily acted upon by moisture. Further, in many cases the silicate compounds formed were found to be acted upon by some of the other components, so that disintegration eventually occurred. This class of materials has, therefore, practically disappeared.

Another material, and one of more promise, employed **hydraulic cement** and water mixed with asbestos fibre. It was formed into thin sheets on a machine similar to a paper-making machine and as many of these sheets were built up as were necessary to obtain the desired thickness. These sheets were cut to size, the pieces placed into molds and held under pressure until the hydraulic cement had undergone preliminary or initial set. Such a material, while somewhat hygroscopic, is still very stable and improves rather than deteriorates with age and climatic exposure. This and other desirable character-

istics have stimulated experiments with this type of substances, and great progress has been made in the manufacture of molded insulation from materials of this nature. The greatest drawback to these early products obtained by the above process was that it was not possible to mold them in any but very simple forms, and they were not made to any extent except in flat pieces.

Mica built up into sheets or formed into shapes was in general use. In this connection no basic improvements have been made, although a great many experimenters have tried to substitute a fireproof or at least a more heat-resisting binder for shellac.

Several patents have been issued and considerable literature has been published relating to **synthetic** resinous products obtained by the condensation of a mixture of phenol and formaldehyde. Such resin-like substances were intended to be a substitute for the natural resinous binders in the so-called shellac compositions. These products were produced in an experimental way, but with indifferent commercial success and were little heard of for several years.

The desirability of a material which, when properly made, would have the easy molding properties of the shellac materials, and in addition possess the great heat-resisting qualities and dielectric strength which these new synthetic products promised, promoted their rapid development, so that to-day such materials are successfully manufactured and are unsurpassed for certain purposes.

Another product of which great success was expected was a composition of **ox blood** and **wood pulp** molded in hot dies in a manner similar to the shellac compounds. This material was obtained by treating the blood to obtain its **fibrine.** This was then dried and powdered

and mixed with the filling materials. The mass was then subjected to hydraulic pressure in hot closed dies.

The binding qualities of the fibrine and consequently the tensile strength of the product was sometimes increased by the addition of **glutinous** or resinous substances. One process employed wood pulp having a large resin content, which under heat, united with the fibrine to cement the mass more thoroughly.

Perfectly molded articles of this type possessing higher heat-resisting properties than the shellac materials were made and used to quite a considerable extent for telephone receivers and similar work; but due to the fact that it is not as readily molded or as chemically stable as shellac, its use has rather decreased than increased within the last ten years.

An entirely different material which has found more extensive use in the domestic purposes than in the electrical arts was formed of **casein,** chemically treated to convert it into a hard, tough substance. This material can be easily molded and worked with tools, but on account of its inability to withstand moisture, its usefulness for electrical purposes is limited.

An attempt was made in England to manufacture a product employing **sulphur** as a binder for organic and inorganic materials, but after a few years of unsuccessful operation the company failed. This process was foredoomed to failure at the start, for it has long been known that metallic parts embedded in hard rubber containing excess of sulphur were energetically attacked by the acids resulting from oxidation of the sulphur, and for this and other reasons this material lasted only until a superior article appeared.

Several attempts have been made to use the waste from the manufacture of **horn** and hoof products by

dissolving or at least agglomerating it by some patented or secret process and afterward welding under heat and pressure. These processes were a total failure. The idea originated from the use of these materials in the manufacture of buttons, hair ornaments and the like, and several factories were started simultaneously in Europe as well as in this country to place materials of this character on the market, and samples, accompanied by glowing prospectuses, appeared; but the samples, after a few months' exposure to the atmosphere, underwent such physical and chemical changes as to demonstrate their unfitness for electrical purposes.

The process of manufacture was to reduce the cleaned raw materials to a powder and to compress this powder in hot dies. If the material had then become sufficiently plastic to mold properly, and if it had coalesced under heat and pressure, it might have had a happier history, but unfortunately it was found necessary to mix with it such reagents as hydrocholoric and sulphuric acids, calcium chlorate, various alkalies, etc., to dissolve, agglomerate or to decompose the powder and render it plastic; and owing to the nature of the chemicals employed and their imperfect combination with the horny substance, the resultant products were very unstable.

Papier Maché formed into various shapes has been widely used both here and abroad. Such products were made by sticking together sheets of especially prepared stiff paper, by means of glutinous substances, and placing the prepared sheets in wood or metal forms to produce the desired shapes. These were placed in ovens until the whole mass became dry and hard. The pieces were then coated with varnishes made of asphalt and resin dissolved in linseed oil or other suitable solvents, and again placed in the ovens. By this means the insulating varnishes were

made to penetrate the surface layers of the paper.

This process was repeated until the paper became covered with a hard, tough, waterproof, insulating surface. As the varnishes employed were the principal insulating elements, it is obvious that the quality of the product depended on them.

Such materials are well adapted to the manufacture of bobbins, large switch box covers having thin walls, and similar parts which it would be difficult to mold of plastic materials, and they are still used to a considerable extent. Such articles are flexible, very tough and fairly good insulators.

Another form of material which has practically disappeared employed cabinet makers' **glue** as a binder for vegetable or mineral fillers. The glue was mixed with the powdered fillers and molded in heated dies or rolled in sheet form, and the sheets were cut to the required size and molded in a heated condition. The products were generally treated with formaldehyde, chromates or other chemical agents to render the glue waterproof and chemically stable. No process, however, was developed which would make animal glue permanently waterproof and stable.

Attempts were made to produce a molded insulating material by treating **cellulose** and celluloid in a number of different ways to reduce their inflammability, but while these materials had great success in other industries, they were of no great value as electrical insulators.

Numerous attempts were made to use **paraffine** and vegetable waxes as binders, but these materials were of short popularity due to their low melting points.

Efforts were made to use the waste of **slate** and **marble** works by reducing it to a fine powder, mixing it with proper binders, and molding under heat and pres-

sure; the resulting products resembled the natural slate and marble, but while such materials are still made to some extent, their use is diminishing.

Another class of materials employing a vegetable gluten for a binding medium was composed of starch or dextrines, and vegetable or mineral fibres. After being molded and dried, the parts were impregnated with mineral or vegetable waxes. Fairly stable materials were thus obtained, but to-day these products are only a memory.

A material was made of the powdered waste of soapstone by mixing it with suitable binders and firing the molded parts somewhat after the manner of porcelain. Such products are still in use and further reference to them will be made in another chapter.

Turf has attracted considerable attention for molded insulation experiments due to its low cost, its wide distribution and fibrous nature. Turf materials made with asphaltic or resinous binders were in practical use for some time, but have almost entirely disappeared owing to their poor heat-resisting qualities.

The following chapters will deal with molded insulating materials employed to-day, including such of the above mentioned early ones as are still in practical use, and eliminating those which have been abandoned.

CLASSIFICATION OF MOLDED INSULATION USED TO-DAY

Molded insulating materials may be broadly grouped into the following classes:

CLASS "A"—ORGANIC HOT MOLDED MATERIALS

Materials obtained by mixing natural organic binders with organic or inorganic fillers, thus mechanically combining the fillers with the plastic binders, molding the mixtures in heated dies, cooling the dies and removing the pieces from the molds in a finished condition.

CLASS "B"—ORGANIC COLD MOLDED MATERIALS

Materials obtained by mixing organic binders in a dissolved condition with organic or inorganic fillers, molding in a cold state and hardening after removal from the molds.

CLASS "C"—INORGANIC COLD MOLDED MATERIALS

Materials obtained by mixing inorganic binders, chiefly with inorganic fillers, molding in a cold state and solidifying after removal from the dies.

CLASS "D"—CERAMICS

Ceramics, known generally under the name of "Porcelain," made from a mixture of China clay, silica

and water, molded in a cold state and heated to a fusing point after removal from the dies.

CLASS "E"—RUBBER COMPOUNDS

Mixtures of rubber or gutta percha generally adulterated with asphalts, oils and other substitutes, mixed with inorganic fillers and vulcanized by well-known processes with sulphur.

CLASS "F"—ORGANIC PLASTICS

Materials made from organic substances chemically treated to render them plastic, and molded into the desired forms. This class embraces a wide range.

CLASS "G"—SYNTHETIC RESINOUS PRODUCTS

Materials obtained by mixing synthetic organic binders with organic or inorganic fillers, and molding the mixtures in heated dies.

CLASS "H"—HARDENED FIBRE MATERIALS

Materials made from paper treated in such a way as to render them hard. The molding of this class is practically limited to the production of sheets, rods and tubes.

CLASS "I"—MOLDED MICA

The qualities of these different products vary widely and there is no one insulating material made to-day which fulfills all the requirements demanded by the various electrical applications.

Some manufacturers claim their products to be suited to all applications, but this is decidedly not so. For instance, while the materials of Class "D" are fireproof, waterproof and inert under all climatic influences, their use is limited to such purposes as do not require accuracy of dimensions or great mechanical strength. While materials made under Classes "A," "B," "C," "E," "F" and "G," on the other hand, can be molded more or less to true sizes and are mechanically strong, they are not as proof against climatic conditions as materials of Class "D."

The electrical engineer has, therefore, to use his own judgment as to the insulator he should choose for his own particular needs, and fortunately he has at his disposal numerous different materials from which he may make proper selection.

While the manufacture of molded insulation is a comparatively new art and much further progress may be confidently expected in the next few years, it has already developed to a point where the products of the various makers are divided into well defined classes which have been on the market and under the test of actual service conditions for a long enough period to enable the engineer to determine which make of material is best suited to his needs.

The manufacture of molded insulation is broadly speaking not a complicated art. It involves a few well defined steps such as the preparing of raw materials,

mixing, molding and finishing, but as is true with many other apparently simple processes it requires long experience to produce satisfactory results.

A proper selection of raw materials is, of course, the first step, but manipulation of the material through all its stages of manufacture requires an intimate knowledge of seemingly unimportant detail. Thus the amount of pressure employed and the speed with which it is applied in the molding process has a very great influence on the character of the finished product. Two pieces having the same ingredients and subjected apparently to the same treatment, while they may be alike in appearance, may vary in their behavior in use. Too little pressure, too great pressure, or pressure improperly applied will produce an article of poor mechanical strength, and of low electrical resistance, and so on through the various other steps of manufacture.

Before going into further detail of these various classes, I will discuss briefly the raw materials employed; explaining their derivation, characteristics, and their properties which render them valuable in the manufacture of molded insulation.

RAW MATERIALS

ASBESTOS

Chemically, asbestos is a silicate of magnesia of fibrous structure. It is mined principally in Canada, Russia, South Africa and Italy. It is generally known as a mineral fibre, supposed to be fireproof and acid-proof. Owing to these properties it is the most widely used element in the manufacture of molded insulation to-day.

The term "Asbestos," however, is broadly applied to various groups of crystalline minerals of fibrous structure, and while they are not affected by the momentary exposure to heat, a continuous temperature of above 900 degrees C. will affect this material so that it loses its chief and most valuable physical characteristic, namely, its fibrous structure.

Mineralogically asbestos is divided into three principle classes, namely, Serpentine, Antophyllite and Amphibole. Each of these groups is sub-divided into several classes.

I refer any one particularly interested in the properties of these materials to the very excellent publication of the Department of Mines, Canada, on the subject, than which no better and more precise publication has yet been issued.

The variety which is of interest to us in connection with molded insulation is the Serpentine class, especially in its chrysolyte form, and I believe the chemical analysis and a short description of this variety will not be out of place here.

The composition of asbestos varies according to the location of the mines, but the following table gives the average composition of the qualities generally used in the manufacture of molded insulation.

Silica (SiO_2)	39.8
Magnesia (MgO)	41.4
Lime (CaO)	.79
Ferrous Oxide (FeO)	1.61
Alumina (Al_2O_3)	1.07
Moisture (H_2O)	15.33

The specific gravity varies from 2.1 to 2.7.

This class of asbestos should not be termed acid-proof, as it is more or less attacked even by weak acids as well as by alkalies.

There are several varieties of asbestos which are acid-proof, but their physical properties are not the same as the Serpentine, inasmuch as the acid-proof asbestos is generally not of fibrous structure, although some acid-proof, well cleaned, fibrous asbestos obtained in Canada and Africa is to be found in the market; but the very high cost of such asbestos makes it prohibitive for use in molded insulation.

Some manufacturers of molded insulation claim their products to be acid-proof, basing their claims on the acid-resisting qualities of organic binders as well as on the supposed acid-proof qualities of the asbestos.

I would, however, caution against the use of molded insulation containing asbestos as a filler for purposes where the product has to withstand the action of acids or alkalies.

While it is true that by intimately mixing asbestos fibre with organic binders the former may be impregnated or coated, rendering the asbestos fibre itself tem-

porarily acid-resisting, it will inevitably succumb to the action of the acid in the course of time.

Asbestos has been of great importance in the development of molded insulation in the last ten years and without it the enormous progress made could not have been effected. Its fibrous structure, no matter how short the fibres, gives the necessary mechanical strength and flexibility, without which the binders in molded insulation would fail.

Its fire-resisting qualities prevent the arc from readily affecting the organic binders, unless the latter should be in too great an excess in the composition.

Asbestos in any composition is entirely inert toward climatic conditions, with the exception that it absorbs water or other fluids. This property renders it valuable, enabling it to absorb the organic binders, and through the high pressure used in molding these asbestos compounds, the fibre is so intimately welded and united that the absorption of water under these conditions is practically nihil. This is especially the case when the amount of binder exceeds the impregnating capacity of the asbestos. While alone, it would be of limited use as an electrical insulator, as it readily absorbs moisture from the air and would, therefore, possess no insulating properties. Combined in proper manner with binders it is one of the most useful elements in molded insulation.

CLAY

Clays are of importance in insulation manufacture. being the principal raw materials of porcelain. For this

purpose clay must possess fineness of grain, freedom from flint and other impurities, and in addition to silica and alumina as its essential ingredients must contain what are known as fluxes. The fluxes commonly employed are lime, magnesia, soda, and potash. They occur in clays in varying amounts. The function of the fluxes is to unite with the silica and alumina, forming fusible bodies, which enable the pieces to be vitrified when fired. Many clays are quite deficient in these fluxes and to these, therefore, fluxes containing the necessary ingredients are added.. Other materials are added to decrease shrinkage during the firing process, the most common of these being sand of a pure grade.

One of the uses of clay in connection with electrical insulation, which, however, is of lesser importance, is as a raw material for the manufacture of Portland Cement. In certain sections of the world vast quantities of clay are so used, the clay supplying the silica, iron oxide and alumina, while limestone supplies the necessary lime ingredients. For this purpose the purity and physical structure of the clay are of minor importance, the essential being that the silica content be from two to three times the content of combined iron oxide and alumina.

MICA

Mica is a mineral of peculiar characteristic striated form and is of prime importance in the electrical arts, because it may almost be called a perfect insulator in its crude or natural state.

It is mined chiefly in Canada, the United States, India, and Siberia, and is found in sheets of laminated

blocks which readily split up into thin sheets along the axis. Its principal use is for electrical insulating purposes, for in addition to its high dielectric strength it possesses great heat-resisting qualities and is chemically inert under ordinary conditions, it is waterproof and acid proof; and these properties combined with its great flexibility make it an ideal insulating material for many purposes.

Chemically it is a Silicate of Aluminum and Magnesium combined with smaller percentages of Potassium or sodium and iron.

An analysis of a kind of mica as used for electrical insulation shows it to be composed of:

Alumina (Al_2O_3)	20.43
Silica (SiO_2)	41.18
Potassium (K)	8.35
Iron Oxide (FeO)	6.
Manganese (MnO)	2.
Magnesium Oxide (MgO)	19.04
Water and other matters (HF—H_2O)	3.

Oil somewhat reduces its insulating value. While mica in its natural state is an excellent insulator, its tendency to split under stress or manipulation renders it necessary in most cases to subject it to some re-inforcing treatment. This is done by separating the mica into sheets as thin as possible and cementing them together with resinous binders under heat, and in this manner sheets of any reasonable dimensions can be obtained, the size of which is not restricted by that of the natural pieces.

Such built up mica can be molded into simple shapes of uninterrupted flat or curved surfaces and has been extensively employed in this manner during the last ten years.

Finely reduced mica, the pulverized refuse of the foregoing and other mica manufacturing processes, are also used in the manufacture of molded electrical insulation. As a filler, such compositions, despite their many valuable characteristics, are inferior to asbestos fibre. Owing to its poor adhesive qualities and its chemical and physical inertness, mica adds no strength to such mixtures but rather weakens them. Its use as a filler, therefore, is practically confined to that type of insulators under Class "A" in which great dielectric strength is demanded, and for this purpose it is far better than any other filler which might be used.

Among the organic materials, shellac adheres most strongly to mica, and, therefore, forms the best binder for mica insulation.

SILICA AND ITS COMPOUNDS

The element Silicon—Si—in combination with two atoms of oxygen, forming the compound SiO_2, is generally known under the term of Silica.

Silicon itself does not occur in the free state on account of its great tendency to combine with other elements; but it is found in abundance in a great many of its compounds, which are of greater importance in connection with molded electrical insulation than any other organic or inorganic ingredient employed.

This is due chiefly to the higher heat-resisting properties and chemical inertness of silica. The hydrosilicate of alumina—Al_2O_3, $2SiO_2$, $2H_2O$—is used in the manufacture of hydraulic cements and porcelain. In the manufacture of the latter, silica in its various forms, such as feldspar, quartz, flint, and sand, serves as an opening, refractory, or as a flux material.

The element silicon, or rather its compound SiO_2, occurs as chief constituent in a further variety of forms, such as kieselguhr, asbestos, mica and talc, all used in the manufacture of electrical insulation.

Silica combines readily at low temperatures with sodium or potassium hydrates to form silicates according to the formula:

$4\ Na\ OH + SiO_2 = Na_4\ Si\ O_4 + 2H_2O$, of which resulting compounds the sodium silicate is of importance.

This soluble silicate, generally known as waterglass, owing to its adhesive properties, is much employed in the electrical art as a fireproof coating and it has been subject to considerable investigation and experimenting for its use as an inorganic binder without attaining, however, any success in this direction.

HYDRAULIC CEMENT

The term hydraulic cement is used to define that class of cements which will harden under water.

This product plays an important part in the manufacture of Molded Electrical Insulation because of its characteristics as a fireproof binder of materials of Class "C," now so widely used in the electrical field.

The essential ingredients of all hydraulic cements are silica, alumina, iron oxide, and lime. In addition to these, magnesia and other impurities are usually present, together with substances added to control the time of set. Of these latter, calcium sulphate is almost universally used.

Hydraulic cements are so old that history fails to reveal their first use. Many of the ancient races made hydraulic cement by mixing together slaked lime and

materials known as "PUZZOLANS." These "PUZZOLANS" consisted of silica, alumina, and oxide of iron, and were usually of volcanic origin. Great care was exercised by the ancients in preparing these cements. They were usually mixed some months before use, and were kept in cool, moist vats, and at intervals were thoroughly beaten with wooden staves in the hands of slaves. In the use of these cements in ancient times the workmanship was of the highest character, and in those days tribes only, who were successful in warfare, became so opulent as to use cement. Such tribes necessarily had plenty of slaves as one of the spoils of war, hence labor was a practically negligible cost. As a result, these people working with hydraulic cements produced results which we to-day are unable to duplicate. The explanation of this is probably to be found in the care in preparation, and in the skilled and thorough workmanship in the use of cements.

For many centuries there was little improvement in the manufacture of hydraulic cements. However, in the early part of the last century, during the construction of canals in New York State, one of the contractors discovered that by calcining and pulverizing certain rock, a very useful hydraulic cement was made. A plant was established and great quantities of this cement were used in the construction of these canals. This cement was given the name of "ROSENDALE," for the district of New York State in which it was first manufactured. In composition, the rock entering the "ROSENDALE" Cement was a limestone carrying from ten to fifteen percent of clay matter.

The temperature of calcination was carried only high enough to expel the carbon dioxide from the calcium and magnesium carbonates present in this rock. No attempt

was made to fuse or vitrify the cement; indeed, if partial or complete vitrification resulted, the product was found to be inferior in quality. Somewhat later, rock of this kind was discovered in the Lehigh District of Pennsylvania, and in Southern Indiana, in Illinois, and near Buffalo, N. Y. Thriving cement plants sprang up in these regions. The class name of "NATURAL" Cements was given to these products, owing to the fact that they were manufactured from natural rock, without addition of any kind. Their use grew to large proportions, until during the nineties several million barrels per year were manufactured.

In 1824 Joseph Aspdin, an Englishman, took out a patent covering the manufacture of a cement by the calcination of a mixture of clay and limestone. He called the resulting product "PORTLAND" Cement, owing to a slight or fancied resemblance to the famous limestone quarried at Portland, England, and known to all English architects and contractors as "PORTLAND STONE."

The work of Aspdin was necessarily of a rudimentary nature, and little attempt was made to closely control the proportions of clay and limestone. Other investigators, however, continued his work, and Portland Cement developed with rapidity. In distinction to Natural Cement, it was manufactured from a mixture of two materials, and was calcined at a sufficiently high temperature to bring about vitrification.

In earlier days, the raw materials were ground in the form of a sort of mud, molded into bricks, which were dried and burned in upright kilns, and these kilns were charged with alternate layers of the bricks of raw mix and coal. When drawn from the kiln, the product had to be carefully sorted, and was then ground to a more

or less fine powder. Extensive research showed that best results were obtained when the finished cement contained from 20 to 23 percent of silica, 5 to 8 percent of alumina, 1 to 5 percent of iron oxide, and from 60 to 64 percent of lime. Chemical control was, therefore, installed in the Portland Cement mills to analyze the raw materials, and so proportion them as to bring this composition into the product. Methods of burning underwent great development, and the rotary kiln utilizing powdered coal came into use, which resulted in great economy. Further refinements were made in the grinding machinery.

With the improvement of Portland Cement, it was found to be superior in many ways to Natural Cement, and, as the cost of production of Portland Cement decreased and energetic competition grew up, the price fell gradually, until, through the combination of the low price and better quality, Portland Cement made serious inroads on Natural Cement, so that today the production of the Natural Cement has fallen to an insignificant figure, while in 1912 there were produced in the United States 90,000,000 barrels of Portland Cement.

A great variety of raw materials is used in the manufacture of Portland Cement, the essential being that they contain silica, alumina, iron oxide, and lime in suitable proportions. A large share of the American production of Portland Cement is made in the Lehigh Valley of Pennsylvania, from material called "Cement Rock." This rock contains the above mentioned ingredients in such proportions that it is in many cases used without the addition of any other material. In other sections of the country, clay and limestone, shale and limestone, marl and clay, and marl and shale, are used. Within the past few years large quantities of

Portland Cement have been manufactured using blast furnace slag and limestone as the raw materials.

ALKALINE EARTHS

The alkaline earths to be considered in connection with molded insulation are lime and magnesia.

In the manufacture of porcelain, the presence of these ingredients is necessary on account of their fluxing action. They are sometimes added in the form of chalk, which is simply a double carbonate of lime and magnesia, and sometimes in the form of feldspar.

Lime and magnesia are of equal importance in connection with the inorganic materials of Class "C." Considering hydraulic cements, lime is an essential ingredient of all cements that have been successfully used as binders in Class "C." For this purpose, the lime is usually supplied by limestone or marl used in connection with clay, shale, or other silicious and aluminous material. The physical characteristics of the ingredients are of little importance, since the burning in the rotary kiln brings about a complete metamorphosis of the materials.

Lime is also present in practically all inorganic binders other than hydraulic cements. The action of these binders is dependent upon calcium silicates and aluminates, formed by proper combination of the acid and basic components.

Magnesia has figured prominently in a type of inorganic binders which more recently have attracted the attention of users of inorganic cold molded insulation.

In 1853, the Chemist Sorel made the discovery that zinc oxide, when properly compounded with a solution of zinc chloride, united with it, forming a very hard cement.

A little later it was discovered that a mixture of magnesium chloride and magnesia also formed a strong cement. Chlorides and oxides of certain other elements possess the same property, but this has been commercially utilized practically only in the cases of the zinc and magnesium compounds. The setting of these cements is due to an oxychloride. Such cements, comprising zinc oxychloride, have found considerable application in dental work. The most important cement of this class, however, is that containing magnesium oxychloride, and this has found important technical uses.

It is made by mixing calcined magnesia with a solution of magnesium chloride of a density of 25 to 30 degrees Baume. When properly made, this cement is superior in strength to Portland cement, but may have certain draw-backs, due to improper methods of preparation, for example; if the magnesia contain a small quantity of residual carbon dioxide, the cement, although attaining great strength, is apt to crack badly during setting; if the magnesium chloride contain sulphuric acid, as is frequently the case, the durability and appearance of the cement are very much injured.

The principal defect of such cements, however, as they ordinarily are manufactured, is that they are not as proof against climatic action as the hydraulic cements.

These cements are used as binders in the manufacture of emery wheels, artificial stone, marble, billiard balls, etc., the fillers employed usually being of inorganic nature. As binders for patent floorings and certain sorts of proprietary plasters, such magnesia cements are incorporated with asbestos, flint, marble-dust, wood pulp, sawdust, and a great many other organic or inorganic fillers. Such compositions have found a more or less commercial application.

VEGETABLE FIBRES

The vegetable fibres most frequently employed in the manufacture of molded electrical insulation are wood pulp and cotton, and to a lesser degree, hemp, flax, and straw. They are employed for the same purpose as the mineral fibre, asbestos, namely; to impart strength and flexibility to the material.

Vegetable fibre, when used in the manufacture of the organic hot molded—Class "A"—the organic cold molded—Class "B"—The Rubber—Class "E"—and the phenol-formaldehyde—Class "G"—materials, is chemically inert and performs merely a physical function in adding mechanical strength and toughness to a merely mechanical mixture.

During the past ten years vegetable fibres have been extensively employed by makers of molded insulation of Classes "A," "B," "E" and "G," because of the following manufacturing advantages which they possess. They impart a fair degree of mechanical strength and owing to the fine structure of these fibres, they are more easily compounded and molded than mineral fibre and consequently the product comes from the dies with a finer and more finished appearance.

Another desirable quality is that, being of a soft nature, materials in which they are employed, have a very much less abrasive action on the dies than those employing mineral fibre. But as they char at about 150-deg. C., they are unsuited to the manufacture of materials to be subjected to any great degree of heat.

Furthermore, their use has been practically restricted to materials employing organic binders and particularly to such using the hot molding process.

Numerous attempts have been made to use vegetable

fibre in conjunction with the inorganic binders such as the silicate or other compounds of lime and magnesia, but with indifferent success for electrical insulating purposes, for while these inorganic substances partly combine with the mineral fillers and make good binders, they do not combine with the organic fillers and their binding value when used with these fillers is small, just as when sawdust is employed instead of sand to make mortar with hydraulic cement the sawdust does not bond with the cement and the resulting mortar is much less strong than when sand is employed.

As an exception, the magnesia chloride cements should be mentioned, which are extensively used as binders for vegetable fibre, but such compounds have not been employed to any extent for electrical insulating purposes and for such purposes vegetable fibre is used only in connection with the natural organic or resinous binders molded under heat.

In case of the materials of cellulose nature and the sheet materials—Class "H"—however, the vegetable fibre plays a more active part. In the former it is employed for its basic chemical principle as cellulose, while in the latter it is employed for its physical structure, the other ingredients being employed solely for their chemical or physical action upon it.

The proper choice of the vegetable fibre in materials of Classes "F" and "H" is of the first importance as in these materials it undergoes definite chemical or physical changes which take place under most delicate conditions.

CAMPHOR

Common or Japan Camphor, as a natural product, is chiefly produced in China, Japan and on the Island of

Formosa. The roots, branches, and trunk of the tree, Laurus Camphora, are cut into small pieces and subjected to distillation with steam. The camphor floats as a white solid, crystalline mass upon the surface of the watery distillation. The older the trees are the better will be the yield and, as a rule, only trees over two hundred years old are used. These yield about three per cent. of raw camphor.

The raw product contains an oil from which the camphor is separated by pressing. This oil, if subjected to steam distillation until about two-thirds of it has distilled over, will yield more camphor, which will settle in the residue.

The raw camphor is then purified by mixing it with charcoal, lime, and alumina and this mixture subjected to sublimation in glass retorts.

Camphor crystallized in the hexagonal system is pure white in appearance and of a strong aromatic odor. Ordinary camphor is dextro-rotatory. The melting point is 175° C., its boiling point 204° C. and its specific gravity .992 at 10-deg. C. Camphor is very volatile and sublimes at ordinary temperature. It is soluble in almost all organic solvents. Small pieces of camphor put upon water show a very lively rotation, which, however, will cease when traces of an oil or a fatty substance is poured upon the watery surface.

Camphor, by reason of its crystaline character, its extraordinary reactivity, its association with the terpenes, and its comparative abundance in nature, has attracted the attention of more than one generation of chemists, and it is, therefore, one of the oldest known organic compounds.

As early as 1785 its effect on nitric acid was known. Camphor has the formula $C_{10}H_{16}O$. However,

no less than thirty different formulae for camphor have been proposed by different skillful chemists during the last quarter of a century, of which that of Bredt so far has received the best confirmation in the discovery of Komppass Synthesis of camphoric acid.

Camphor, synthetically made, is identical with the natural product in its form of crystallization, in its melting point, solubility, etc., but is levorotatory.

Camphor plays a very important part in the nitrocellulose industry, as it will form with pyroxylin or nitrocellulose a so-called solid solution generally known as celluloid, a plastic of remarkable flexibility and elasticity.

Although numerous attempts have been made in the celluloid manufacturing processes to replace camphor with cheaper substances, none has been successfully applied as yet.

WOOD PULP

This product is obtained by disintegrating wood. The wood fibres are separated either mechanically or chemically.

The first variety is prepared by grinding the wood under water, and is of inferior quality, as the fibres are short. The superior grades are prepared by chemical means. The wood is cut up and boiled under pressure with a solution of caustic soda, sodium sulphide or, best of all, calcium bisulphite, and the resulting soft product is pulped, pressed, and washed.

A special grade of wood pulp is used as an initial celluloid product in the manufacture of certain low priced celluloids.

It is used extensively as a filler in such hot molded

materials as Class "A" and in the Phenol-Formaldehyde products of Class "G."

It is the raw product in the manufacture of vulcanized fibre and other fibrous insulating products described in Class "H."

COTTON

Is a plant of the genus gossypium. It is one of the most important vegetable fibres, and on account of its characteristic spiral thickening is readily distinguished from all others and is especially adaptable to spinning.

At least fifty species of Gossypium are known, nearly all of which produce lint upon their seeds, but very few enter into consideration in the production of the commercial crop.

The Upland cottons of the United States are variously referred to as Gossypium Herbaceum and Gossypium Hirsutum.

In this country two distinct types of cotton are recognized. The Sea Island, with its small, smooth, black, seeds and long, fine lint, and the Upland type with a greenish seed, shorter lint, and a closely adherent fuzz about the seed, known as linters. The Sea Island Cotton is grown to greatest perfection on the islands and low-lying coast of South Carolina, Georgia and Florida; also in the West Indies and in Egypt.

The fibre, when well-grown, measures 1.5″ to 2″ in length, and being very fine, is in constant demand for the finer numbers of threads and yarns, for which it commands a high price.

The Upland cotton is grown over a wide area of the United States and furnishes by far the greater portion

of the crop. It is cultivated throughout the region from Virginia to Oklahoma, and southward.

The fibre of this type is usually shorter and coarser than that of the Sea Island, but by careful crossing and selection, varieties are being secured that approach the lower grades of Sea Island in quality.

Cotton is an initial raw material in the manufacture of celluloid and its treatment for such is described under the chapter devoted to that material.

It is also employed as a fibrous filler in the manufacture of the hot molded materials of Class "A."

From it, the better qualities of the vulcanized fibre or other paper insulating products are made, but owing to its high cost, it is not used to any great extent for such purposes.

HEMP

Cannabis Sativa is an erect growing plant originating in Asia. It resembles very much in its general appearance the common stinging nettle. Both belong to the same family—Urticaceae.

Its cultivation is similar to that of flax. The young plants are thinned out when they are three or four inches high, and are left from eight to twelve inches apart. If intended for fibre alone, the stems are all pulled and treated alike and it is principally for its fibre that hemp is cultivated. This is obtained by rotting the stems of the plant, on the same principle as is followed in separating flax fibre.

Hemp is grown in the Philippine Islands and Europe.

FLAX

Flax or Linum Usitatissimum belongs to the natural order of Linaceae and is unknown in the wild state. Its cultivation dates from pre-historic times, bundles of unworked flax having been found in the ancient lake dwellings in Switzerland.

The flax fibre is found within the cortex of the stem and is easily separated after the flax straw has been rotted in water. This process is followed by drying and stacking, and afterwards by breaking and scutching, which completely separates the fibre.

Flax is produced principally in Austria, Belgium, France, Germany and Russia. It is also grown in the United States, but in this country it is cultivated almost entirely for its seed and not for its fibre.

The flaxes are herbaceous or sub-shrubbery plants, their stems being remarkably tough.

New Zealand flax is a liliaceous plant and also yields a valuable fibre, which is stripped by machinery and used for making baskets, ropes, etc.

Flax is comparatively of little importance in connection with the manufacture of electrical molded insulation.

ASPHALTS

The term "asphalt" is applied to a series of bituminous substances generally black in color, which are hard at ordinary temperatures, become viscous at about 70-deg. C., and melt at about 100-deg. C. Their specific gravity varies from 1.04 to 1.40. Chemically, they are compounds of carbon and hydrogen and their sulphur and nitrogen derivatives.

They may be divided into two groups; the "NATURAL" and the "ARTIFICIAL."

Natural asphalts occur in various parts of the world, notably in United States, Trinidad, Barbadoes, Venezuela, Mexico, Cuba, Egypt, Russia, and India. They are found as mineral deposits embedded in the earth, sometimes containing lime and other impurities, or in the so-called asphalt lakes, such as those in Trinidad and Venezuela.

The asphalts in which we are particularly interested are the mineral asphalts of Utah, Colorado (Gilsonite) and Barbadoes (Manjak), which are peculiarly free from impurities and are the ones generally employed in the manufacture of electrical insulation.

The "ARTIFICIAL" asphalts are prepared by the distillation of asphaltic petroleum, resemble the softer natural asphalts in some respects and are often marketed as such, especially when prepared for some specific purpose.

In addition to the natural and artificial asphalts, coal-tar residues or pitch, derived from the distillation of coal tar, are extensively used for many similar purposes. Coal-tar pitch differs materially in chemical composition from the natural bitumens. It is more brittle than the hard asphalts, but melts more readily and is more fluid under heat. The artificial asphalts and coal-tar pitch are both extensively used in the manufacture of electrical insulation and for this purpose are about as equally valuable as the natural asphalts.

Stearine Pitch, obtained as a by-product in the treatment of vegetable and animal oils and fats for the production of stearic acid, is much softer than those mentioned above and is of great value in insulating compounds, because of its ability to stand very high temperatures without drying out and becoming brittle, and is employed

in the manufacture of insulating varnishes, cloths, and tapes, as well as in binders for the manufacture of molded insulating parts.

Ozokerite, a solid bitumen, consisting largely of paraffine hydro-carbons, and ceresin wax prepared therefrom, are important raw materials used for insulating purposes. "CERESIN" Wax melts between 60-deg. C. and 70-deg. C., and owing to the fact that it then becomes a very limpid fluid, it has much higher saturating qualities and is a far better impregnating material for tapes, clothes, and molded insulating pieces than the heavier and more viscous asphalts or pitches.

Pitch obtained from the distillation of wood and brown coal is also used to some extent, but due to its very brittle nature is of comparatively little value.

It is self-evident that the harder the asphalt, that is the higher its melting point, the greater will be its heat-resisting properties, but unfortunately, the brittleness increases with the hardness.

The chemical and physical characteristics of some asphalts are such that they are well suited for use in compounding with rubber, and for this purpose are extensively and successfully employed.

Pure asphalts and mineral pitches are unaffected physically or chemically by water, acids, or alkalies and this inert characteristic coupled with their high di-electric strength, their low cost, and the facility with which they can be manipulated, renders them of the greatest importance in the manufacture of electrical insulating materials.

They have a considerable advantage over the copal resins in that they do not have to be distilled to render them suitable for the manufacture of varnishes and other compounds used in the preparation of binders employed

in the manufacture of molded insulation, as they fuse or melt readily when subjected to heat.

SHELLAC

The story of the production of shellac is perhaps more interesting than that of any other material used in the manufacture of molded insulation.

Lac is a vegetable substance as it is the sap of a tree, but it is also an animal product in that it is exuded by an insect.

These insects (the coccus lacca, carteria lacca, etc.) infest several species of trees growing in India and southern Asia, notably certain varieties of fig trees.

The female produces the lac to protect her eggs. This insect, after attaching itself to the plant, remains fixed there and proceeds to extract the resinous sap and to convert it into lac, with which she incrusts herself and in which she deposits her eggs.

In a short time, the eggs burst into life, and the young, which are very minute, eat their way through the dead bodies of their parents, and swarm all over the twig or small young branch of the tree in such countless numbers as to give it the appearance of being covered with a blood-red dust.

The method of preparing the lac for market is crude but effective. The incrusted twigs, when broken from the trees, are known as stick lac. The brittle lac is readily removed from the sticks by means of rollers.

The crude lac, which is of a dark red color and contains about 68 per cent. resin, is now placed into tubs of warm water and beaten with pestles or trodden by men. By

this means it is freed from the bodies of the insects, the dirt, vegetable matter, and much of its coloring.

The lac, now termed seed lac, is removed from the matter and the latter boiled down and molded into cakes. This product, known as "lac-lake," was very widely used before the introduction of coal-tar colors as a red dye for textiles, and is still much used in the countries where it is produced.

The seed lac is now placed in cotton bags and held before a charcoal fire, the melting lac being squeezed through the cloth by twisting the bag. It is now ladled from the trough into which it has dropped and poured over and spread upon a slowly revolving roller upon which it soon sets and hardens, when the thin shell of lac is cut or scraped from the roller with a knife, and the shell lac or shellac is ready for market.

The best of the shellac made in this way is of a light brown color, nearly transparent, and is known as "orange shellac."

The lower grades, not so free from coloring matter and foreign substances, are usually molded into thin sheets or discs and sold under the names of button lac, garnet lac, etc.

It is chiefly used as a binder for materials of Class "A." It melts more perfectly than asphalt or other natural resinous bodies, with the exception of rosin, although its melting point is higher than these adulterants.

It is impervious to water and stable under ordinary climatic conditions. It forms a very tough binder and is superior in this respect to asphalts, pitches, and resins, but unfortunately much liable to adulteration with the latter, owing to its higher price.

Shellac is also used as a binder for mica and its binding qualities for this material are superior to any

other kind known to-day.

It is used extensively in solution in alcohol as a quick drying insulating varnish.

It is, or ought to be, the principal ingredient in the manufacture of insulating sealing waxes, used for sealing up metal parts in assembled porcelain insulators, but unfortunately, as in the case of molded insulating materials of Class "A," it is replaced for this purpose by cheaper resinous products such as rosins, asphalts, etc.

RESINS

COPAL

This term is broadly applied to a number of fossil gums. The botanical origin of these resins is not definitely known although some of them, particularly those of more recent fossil origin, can be partly traced to trees, species of which are still extant.

The copals are found chiefly in East and West Africa, New Zealand, Java, South America and the Philippine Islands. The older fossils are collected by natives employing very primitive methods and are gathered from the beds of lakes and streams or dug from the earth during the wet season by open mining to a depth of about fifteen feet.

Copal is found in the market in many shapes and varies greatly in color. In form it ranges from small pebble like particles to blocks two feet in diameter. The size depends on the kind of copal. It is also found as chips, slabs, and angular lumps of irregular form. It is usually of a yellowish or brownish amber color and is almost always covered with a crust of variable color,

which must be removed in water or lye or by mechanical means, the latter method being preferable.

In quality copals are graded according to the following characteristics:

Hardness or toughness.
Color.
Solubility and melting point.

The harder copals, Zanzibar, Mozambique, Sierre Leone, Angola, Benguella, Gabon, are usually the higher priced. Among the softer copals are the Manilla and the Kauri.

The melting point of copals varies from 75-deg. C. to 450-deg. C., the harder having the higher melting points.

The solubility of copal has been the subject of much analytical research and while many of these gums are more or less soluble in alcohol, ether, benzol, benzine, acetone, turpentine, chloroform and carbon disulfide, in manufacturing it is practical to dissolve them only after they have been melted. This process is briefly as follows: the copal, after having been cleaned, is sorted according to color and size and the larger pieces crushed or ground. It is then heated to get rid of such water as may be present and then melted over an open fire or subjected to a process of destructive distillation to drive off the resinous oils. The loss from this operation varies from 10% to 40% by weight. The process is one requiring great care and experience, for the point at which the melting or distillation is arrested plays a most important part in the value of the product. This point is determined by collecting and watching the amount of resin-oil distilled over or by carefully watching the appearance, temperature, and condition of the melted resin and de-

pending upon the skill and experience of the operator, the latter method usually giving the better results.

If the heating is carried too far and too much oil is driven off, not only is the loss in weight unnecessarily great, but the copal loses some of its toughness and other desirable qualities. The interruption of the distilling process at the proper moment is, therefore, of prime importance.

After being subjected to the distilling process, as described above, the copal gums are soluble in various oils and other solvents, and in such form are of the highest importance in the electrical art, not only in the field of molded insulation, but to an even greater extent for a wide range of uses in the preparation of insulating varnishes, impregnating compounds, insulating cloths, and the like. Copals and copal preparations, when properly prepared, are unaffected by climatic influences, especially those of the earlier fossil origin, and in proper combination with suitable solvents and inorganic admixtures possess great heat-resisting and dielectric properties and will withstand continuously a temperature of 200-deg. C. These properties render copal one of the most important materials in common use in electrical manufacture.

While the chemical nature of copals is as yet undetermined, or at least but incompletely determined, their physical properties render them of the utmost importance in the electrical arts.

RESINS

DAMMAR GUM

This variety of resin is obtained from the amboyna pine and comes principally from Java and Sumatra. It

exudes sap naturally like the spruce and other members of the pine family, but this yield is increased by making incisions in excrescences which grow on the trunk of the tree. It is also gathered in considerable quantities from the beds of streams flowing through the districts in which the tree is found. It comes to the market in small, usually transparent, homogeneous, lumps. Its principal use in insulating manufacture is in binders for the hot molded organic materials (Class "A").

It begins to melt at 80 deg. C., and at 100-deg. C. it commences to flow rapidly. It does not melt as readily as rosin, but more readily than other resins of the copal series.

It is soluble in benzole, turpentine, and ether without the application of heat. It is also soluble in benzine, in which it differs from most other resins.

Although affected by atmospheric exposure, it is much more stable under these influences than rosin and is much to be preferred to it, and would supersede this gum entirely were it not for its higher cost.

ROSIN

The term, rosin, is applied to the residue obtained from the distillation of the resinous exudation of various species of the pine tree, the volatile portion which distills over being turpentine.

It is found in the market in hard, homogeneous masses and varies greatly in quality. The quality depends upon the percentage of turpentine distilled off as well as upon the quality of the resinous exudation from which it was derived. In color, it varies from a light, transparent,

yellow amber to almost black. It is quite hard and very brittle and softens readily under heat at 75° C., becoming a thin liquid at about 100° C., above which temperature it decomposes.

It has the property of becoming a limpid liquid at comparatively low temperatures, which makes it so useful a substitute for shellac in the organic cold molded materials. It is not much used in the manufacture of electrical insulation, except for this purpose, but finds manifold uses in various of the liberal arts.

The use of rosin in the manufacture of molded insulation should be discouraged, since its cheapness is its only recommendation. Many attempts have been made to render it more heat-proof and to give it a more stable nature, but while much literature has been published on this subject, very little practical result has been attained.

PARAFIN WAX

This term is applied to a variety of hydrocarbons of the paraffin series, obtained from shale oils. It is a solid softening readily at 50-deg. C., and was formerly used for impregnating electrical insulation materials.

But owing to its low melting point it is but very little used for such purposes to-day.

The reason it retains its place among the substances in use for the manufacture of electrical insulating materials is that it will withstand the action of alkalies better than any other organic insulating substance. It is also unaffected by strong acids at ordinary temperatures.

LINSEED OIL

This oil is obtained by pressing the seeds of the flax plant. According to the character of the seeds and the method of extraction employed, the oil varies from a pale, tasteless, product to an amber or yellowish colored, limpid, liquid of characteristic taste.

It is of incalculable value in the electrical arts and is extensively employed in conjunction with resins and asphalts for the manufacture of varnishes and impregnating compounds. In such preparations, it acts not only as a solvent, but due to the fact that it absorbs oxygen from the air, it has an oxydizing effect upon the resinous and asphaltic bodies with which it is mixed. This is particularly true of the boiled linseed oil, which will continue to increase in weight by the absorption of oxygen from the air until it becomes viscous or even hard. In practice. this drying or oxygen absorbing property is increased or hastened by the addition of metallic oxydizing agents.

Linseed oil is used not only in combination with other substances, but the boiled oil itself, without other admixtures, except, perhaps, driers, is used to a considerable extent for impregnating and coating clothes and tapes as well as for treating molded insulation and insulating parts.

A number of methods have been proposed and considerable patent literature is available relating to the production of solid resinous products from linseed oil which might be substituted for shellac asphalts or resins in the manufacture of molded insulation. The object of these experiments was to take advantage of the high heat-resisting properties of the resinified linoxen products in the manufacture of such materials as those of Class "A" (the organic hot molded materials), but no

great success has been attained in this direction, partly owing to the fact that one of the chief advantages of employing shellac and similar binders for materials of this class lies in their property of becoming plastic under heat during the molding process, and the linoxen products are far less plastic than shellac and consequently are not so easily molded.

On the other hand, considerable success has attended the compounding of linoxen products with rubber and asphalts to produce rubber substitutes which are successfully employed in the manufacture of molded insulation.

Another interesting application of linseed oil which has been proposed, consists in heating cellulous, starch, refuse horn, hoof by-products, and other materials, with linseed oil to a temperature beyond the point of decomposition, at which temperature the components were supposed to react upon each other to form a new resinous substance.

Unfortunately, beyond laboratory experiment and elaborate patent literature, nothing noteworthy was developed.

Owing to its high price, linseed oil is subject to much adulteration and replacement by rosin oil, mineral oils, and other cheaper oils, and, while it is often difficult to detect the presence of such adulterants analytically, their imperfect drying and poor elastic qualities soon proclaim them in practice.

VARIOUS OTHER DRYING OILS

Besides linseed oils, there are a few other oils used in connection with the utilization of resins and asphalts for insulating purposes.

Among such the following are worthy of mention:

Chinese wood oil or Tung oil: This oil is obtained from the seeds of the Ying tzu tung, a tree indigenous to China, and is used in very considerable quantities as a substitute for linseed oil. This product exhibits one marked difference from linseed oil in that it dries at a uniform rate throughout its mass, whereas the latter dries from the surface inward.

Soja bean oil: Obtained from the fruit of the Soja bean tree.

Poppy seed oil: Obtained from the plant Papaver Somniferum.

Rosin oil: Obtained from the dry distillation of rosin. This oil, owing to its low price, is a common adulterant of linseed oil. Its drying qualities are not equal to those of linseed oil and it is of such an unstable nature as to make its use inadvisable for electrical insulating purposes.

MINERAL OIL SOLVENTS

Various derivatives distilled from petroleum and coal-tar at different temperatures are employed in the manufacture of liquid compounds of resins and asphalts.

They are usually cheaper than the drying oils and do not dry, or rather evaporate readily, which is a source of frequent complaint from users of these liquid solutions or compounds.

They are employed in the manufacture of impregnating compounds and cheap insulating varnishes, as well as for impregnating insulating cloths and tapes.

Their evaporative qualities vary greatly. Some will dry or evaporate on exposure to the atmosphere, while

others require considerable heat. This variation renders them applicable to a wide range of purposes.

TURPENTINE

This well-known solvent is obtained from the distillation of the exudations from various species of the pine tree. It is the volatile product of the distilling process, the residue being rosin.

It is much valued for its use in connection with dissolving waxes, resins, and similar materials used for electrical insulating purposes.

When exposed to the air, it dries slowly but steadily by absorbing oxygen. The major part of it evaporates, leaving a minor part of resinous hard substance behind.

In this respect of drying by absorption of oxygen, turpentines differ from other solvents, such as naphtha, benzol, etc., as these latter solvents evaporate rapidly and leave no residue behind.

BENZINES

Benzene obtained from the distillation of coal-tar, and the benzine or benzoline obtained from the distillation of petroleum oils, are both widely used as quick volatile solvents for asphalts, resins, and copal oil compounds, because of their excellent dissolving properties and volatile characteristics.

ALCOHOLS

Among the alcohols ethyl or grain alcohol and methyl or wood alcohol are both used to a considerable extent for dissolving the resinous organic binders in the manufacture of insulation products.

They are principally used to dissolve shellac and other alcohol soluble gums. Such solutions are also of great importance in the manufacture of built up mica and quick drying shellac gum varnishes.

CAOUTCHOUC OR CRUDE RUBBER

This is the name given to the product of the milky latex which exudes from incisions made in the bark of certain trees found in tropical and semi-tropical countries.

While many trees produce this latex to a greater or lesser degree, there are certain regions which, in the quality and quantity of this product, surpass all others. At the present time the rubber trees found in the Amazon District of South America give a latex which in purity and quantity surpasses any now known. Generally speaking the world's supply of crude rubber comes from Central America, South America, Africa, and Asia. The quality of the rubber is rated in the order named.

While the methods of handling are different in the various districts, the ultimate result is the collection of the milk or latex found in the bark of the trees, and the reducing of it by certain processes to the commodity known as crude rubber. The latex consists of rubber, resins, and other organic substances, and water. In the Hevea plant, which is considered one of the best of the Amazon trees, only 30% to 32% of the latex is rubber. In other trees the percentage is even less. Crude Rubber contains more or less foreign matter according to the manner in which it is collected.

In the Amazon District care is taken to prevent the latex from coming in contact with alien matter with the result that the loss due to this cause is very small. The

African and Asiatic trees are carelessly cut and handled, often permitting the flowing latex to drip down the sides of the trees to the ground with the result that stones, earth, leaves, etc., are collected with it. The loss from such careless methods is often as much as sixty per-cent.

The consumption of rubber is steadily increasing and new uses are being found for it every day. Consequently the supply of crude rubber is naturally one to be looked to with some concern. The likelihood of an inadequate supply before many years and the constantly increasing price of crude rubber has resulted in the planting of rubber trees in the districts where these trees are found in their native state. The rubber obtained from such cultivated trees is known as "PLANTATION" Rubber and is usually of a higher grade than the wild rubber.

Rubber in its crude state is very seldom used commercially as it is very susceptible to atmospheric changes. At a temperature of 51.7 deg.C. it becomes very sticky and has great adhesiveness, while at 0 deg. C., it is very hard and brittle and is easily broken. To overcome these faults the process known as vulcanization is resorted to, the principle of which is the incorporation of sulphur in some form and the subsequent heating of the mixture. The sulphur in general use for vulcanization is in the form of flowers of sulphur. This form of sulphur has a specific gravity of 2.00 and in good commercial form is of a bright, lemon color. It is insoluble in water and alcohol and mixes readily with crude rubber. In mixing the sulphur with the rubber care is taken to thoroughly incorporate it by running the two materials together through iron rollers which are so geared as to travel at different speeds, which in so doing not only press the materials thoroughly together, but

also exert a pulling stress upon the mass. Crude rubber when properly mixed with sulphur and vulcanized undergoes changes in both its physical and chemical properties. It is not then affected by ordinary changes of temperature. Its elasticity is greatly increased, and it is not soluble to any great extent in such agents as naphtha or chloroform, which, before the admixture, readily reduced it to a liquid solution.

There are a number of methods of vulcanizing rubber, the principal one being known as the steam process. In this process the steam may come in direct contact with the mass held in a large cylinder or tank, or the heat of the steam may be exerted on the outside of a mold which holds the rubber mass, this mass having no contact with the steam itself. Before being subjected to the heat the sulphur, to the amount of from 3% to 60%, is thoroughly mixed with the crude rubber. As sulphur fuses at about 113 deg. C., it is necessary to subject the sulphur impregnated rubber to a heat of at least this temperature. It has been found by experiment that when such rubber is subjected to a temperature of over 150 deg. C., for any length of time, the mass shows a tendency to carbonize and harden. So for all practical purposes the temperatures are kept between 130 deg. and 140 deg. C. relying on the length of time to produce the desired hardness or density in the finished article. In the manufacture of hard rubber the mass is sometimes vulcanized at a temperature of 160 C. for six or seven hours.

In the manufacture of rubber goods, the purposes for which the article is intended must be taken into consideration. Where soft, pure rubber would work to advantage in one place, it would prove a failure in another. It can be readily seen that while a pure, elastic, rubber

stock would act to advantage in flexible insulating tubes, the same stock would prove a disadvantage in the molding of solid insulators. Consequently, certain chemicals and minerals in addition to the variable proportions of sulphur are incorporated with the crude rubber, this admixture depending upon the purpose for which it is to be used.

When the finished article is intended to resist heat. as for electric insulation, minerals which are known to possess heat-resisting qualities, such as asbestos or other inorganic fillers, are added in greater or lesser quantities.

Hard rubber or ebonite is prepared in practically the same way as vulcanized rubber. Sulphur to the amount of 30% and sometimes over 50% is added to the crude rubber and it is subjected to a temperature of over 150 deg. C. for several hours.

As an electrical insulator, rubber must be rated highly. It has been found that rubber in its unvulcanized state has a higher dielectric strength than after being vulcanized and that compounding with chemicals and minerals decreases this property in proportion to the percentage of chemicals and minerals used.

Inasmuch as sulphur is also a good insulator, crude rubber, mixed with sulphur alone, is sometimes used for electrical work, but on account of the cost of the rubber, compounding to the extent of 50% to 90% is often resorted to.

While many substitutes for rubber have been offered, they lack the excellent toughness and elasticity which rubber possesses and till these substitutes can be produced possessing these qualities and at a lower cost than rubber, the latter will continue to hold its own.

Vast amounts of money and effort have been ex-

pended throughout the civilized world in attempts to produce rubber by artificial means and it seems as if at last success was in sight.

These efforts have for some time past centered on the cheap production of isoprene, the essential constituent of India rubber.

The new process from which so much is expected, is based on using starch as an initial raw material, producing therefrom amylalcohol by a process of fermentation and converting the amylalcohol by certain chemical manipulations into the unsaturated hydrocarbon isoprene.

Isoprene had previously been produced from various substances, such as from turpentine, acetylene, and ethylene, but due to the high and fluctuating cost of these materials, the production of synthetic rubber had not made any remarkable progress until the discovery of a method of deriving isoprene from so simple, cheap, and readily obtainable a material as starch.

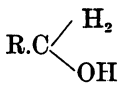
Isoprene when properly treated will polymerize into rubber.

The process here referred to is comparatively new and it is too soon to make positive predictions as to the success of this very interesting development in this important art, but the future of a process depending on so cheap and simple a raw material is full of promise and it looks as if the goal for which so many investigators have so tirelessly striven is at last almost attained.

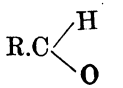
FORMALDEHYDE

Formaldehyde (Methylaldehyde, or Methanal) H.COH is the oxydation product of Methylalcohol CH_3OH and the Aldehyde of Formic-acid HCOOH It is the

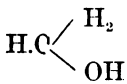
simplest type of all Aldehydes, the latter being the oxydation products of the primary alcohols. This may be shown in the following schemes:



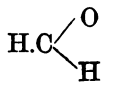
Prim. Alcohol



Aldehyde



Methylalcohol



Formaldehyde

"R" Indicating any organic radical or element whatever. Though Formaldehyde was discovered as early as 1867, and although its important functions in the process of assimilation in plant life has been recognized by prominent chemists for many years, its technical use and manufacture on a large scale dates back only to about 1886.

Formaldehyde at ordinary temperatures is a gas of pungent smell, which at —21-deg. C. condenses to a colorless liquid. In commerce, it usually occurs in a watery solution of about 35% to 40%, which is known under the technical term of "FORMALIN," or in its polymerized and solid forms as the so-called "PARAFORM" $(HCHO)_2$ or as "TRIOXYMETHYLENE $(HCHO)_3$.

Formalin, however, is the usual commercial form of Formaldehyde.

By the incomplete oxydation of methylalcohol, the latter being mixed with air, in the presence of any contact substance (catalyser) usually granulated copper, Formaldehyde is produced as an intermediate product between methylalcohol on the one hand and formic acid on the other hand. This process formulated in the equation:

$$CH_3\,OH+O=HCOH+H_2O$$

is at the present time the usual way of manufacturing Formalin.

On further oxydation Formaldehyde yields formic-acid and finally carbonic-acid:

$$HCOH+O=HCOOH$$
$$HCOOH+O=CO_2+H_2O$$

The oxydation with copper as a catalyser starts at a temperature below 300-deg. C. By carefully watching the temperature and not allowing it to rise too far above 300-deg. C., the quantity of carbonic acid produced will be negligible. The methylalcohol present in excess in the watery Formaldehyde solution is separated from the latter by fractional distillation in column dephlegmators.

The aqueous formaldehyde solution of commerce, however, contains about 10% of methylalcohol, which prevents the polymerization of the formaldehyde.

Formalin, like the gaseous formaldehyde, has a pungent odor and shows frequently a slightly acid reaction due to the formation of traces of HCOOH. The specific gravity of formalin of the usual commercial strength of 35—40%, is 1.081 to 1.097.

A few other processes of more scientific interest may be briefly mentioned here.

If a mixture of methan CH_4 with a quantity of air insufficient for a complete oxydation, is passed over glowing copper or asbestos, formaldehyde is produced.

Formic acid is transformed into formaldehyde by mixing the acid vapors with hydrogen and passing this mixture over iron, nickel, zinc or other metals, at high temperatures.

By evaporating an aqueous solution of formaldehyde, paraformaldehyde $(HCOH)_2$ is produced as a white amorphous mass, which on drying passes into the other modi-

fication, trioxymethylene $(HCOH)_3$. This body is volatile at 180—200-deg. C. turning into formaldehyde again.

Formaldehyde, as the first and lowest type of the aldehydes possesses an enormous capability to undergo reactions with other compounds, even with such comparatively indifferent bodies as kerosene oil or benzol.

Formaldehyde precipitates mercury and bismuth in alkaline solution. It reduces silver even in its insoluble chloride, and silver mirrors are made by the action of gaseous ammonia upon a paste of silversalt—formalin.

With ammonia and formaldehyde hexamethylene-tetra-amine $C_6H_{12}N_4$ is formed. When boiled with lime-water it yields formic-acid and an amorphous saccharine substance—methylenitán.

Its condensing reactions are very numerous, and it is chiefly due to this circumstance that its technical application has increased so enormously within the last twenty years.

Formaldehyde condenses with dimethylamin into tetramethyl-diamidodiphenylmethan, the raw material of the leuko-base of Krystallviolet. Also other dyestuffs like parafuchsin, neufuchsin, etc., are made by means of formaldehyde.

Besides its use as a disinfecting material instead of phenol and mercury bichloride, it finds a large application as a preservative for crude, raw products, in tanneries, soap works, etc. It is often added to glues, gums, or starch solutions for a similar purpose.

Its applications in many industries, such as in photography, leather making, and in the manufacture of india rubber goods, etc., are very great. It condenses with phenols producing resin-like bodies, which, besides being the raw materials of many substitutes for amber, hard rubber, bone, etc., have proved to be substances of high

insulating power, wherefore, this condensation reaction of formaldehyde with phenols will be treated in this book in a special chapter under "CLASS 'G.'"

PHENOL

Phenol is the type of a series of organic compounds which form a class by themselves as derivatives of the so-called aromatic compounds, the latter having as their representatives benzene or benzol.

As the chemical structure of both bodies readily shows, phenol results theoretically from the substitution of one H-atom in the benzol nucleus through the hydroxyl—or OH group—this radical being the typical chemical characteristic of all phenols.

Whereas phenol itself, as the first representative of the phenol group, contains only one OH radical, it is possible to substitute gradually all 6 H-atoms in the benzol nucleus, thus arriving at higher phenols.

Since the H-atom of the phenol—OH group, is of a more electro-negative character than the hydrogene of the alcohol-OH group, we may consider the phenols as a group, standing between the alcohols and the acids. This explains the term carbolic acid used sometimes instead of the more scientific name "PHENOL."

Phenol, discovered in 1834 by Runge, occurs very widely in the animal, as well as vegetable kingdom. As a product of the change of matter in the human and animal body it occurs in the urine. Furthermore, phenol or its homologues, is formed by the decay of albumin, tyrosin and the like, and especially by the destructive distillation of organic compounds, as, for instance, wood and bones, also by the dry distillation of bituminous and

anthracite coal. It occurs in the needles and sap of pine wood, in mineral oils, and is technically one of the most important constituents of coal tar, the latter being the main source of its manufacture. Although synthetic methods of manufacturing phenol are well known, its production from coal tar is still the most usual and economical way.

As the phenol is soluble in caustic alkali, it can easily be isolated from coal tar by agitating the latter in the solutions of the former. Acids will then separate the free phenol from the solution. The phenol itself is then purified by fractional distillation.

The chemical part of this comparatively simple process is shown by the equations:

$$C_6H_5OH+NaOH=C_6H_5ONa+H_2O$$
$$2C_6H_5ONa+H_2SO_4=2C_6H_5OH+Na_2SO_4$$

Phenol is also soluble in concentrated sulphuric acid, thus forming sulphonic acid.

Due to this reaction, practical manufacturing processes have been introduced to separate phenol from the tar oils; although their yield is not quite as satisfactory as that produced by the alkali method.

Of the synthetic processes of producing phenol, two may be mentioned on account of their greater importance in the art.

They are the methods of Griess, and Kekulé, Wurtz and Dusart.

Griess produced phenol on a large scale by boiling the diazocompound of aniline diluted acids.

Kekulé, Wurtz, and Dusart have found independently of each other, that benzolsulphonic acid is turned into phenol and potassium-bisulphite by fusing it with

potassium hydroxyd, the chemical reaction being as follows:

$$C_6H_5SO_3Na+NaOH=C_6H_5ONa+NaHSO_3$$

This synthesis especially was successfully applied for some time when the market price of phenol was high enough to permit it. The resulting phenol showed a remarkable purity and a somewhat weaker and more pleasant odor. But as the same result is now obtained in a cheaper way by the production of phenol from coal tar, as mentioned above, the synthetic methods are nowadays almost entirely abandoned.

In a pure state, phenol crystallizes in long white needles, which melt at 42.2-deg. C., and boil without being decomposed at 183—184-deg. C. Ordinary phenol, however, melts somewhat lower, usually at 35.5—40.5-deg. C., due to traces of cresol or water. The specific gravity of phenol at 18-deg. C., is 1.065.

Owing to its hygroscopic qualities, phenol exposed to moist air, takes up a considerable amount of water and the melting point is lowered.

Though hygroscopic, phenol itself is not very readily soluble in water, one part of phenol dissolving in 20 parts of water at ordinary temperatures. Other solvents like alcohol, ether, benzol, glacial acetic acid and glycerine, on the other hand, dissolve phenol in all proportions.

Phenol can be extracted from its watery solution with benzol, ether, carbon disulphide or chloroform. The watery solution does not redden litmus.

Phenol has a peculiar smokelike smell, it attacks the skin very violently and is poisonous in its internal effects, due to its property of coagulating albumin.

Of its many characteristic reactions the more important ones may be mentioned.

Ferichloride, not in excess, gives a violet color with one part of phenol solution to 3,000 parts of water.

Twenty cc of a solution of phenol to 5,000 parts of H_2O show on gradual heating with ammonia and Eau De Javelle, a deep blue color, which is changed by the action of acid, to red.

Phenol, added to a solution of nitrous acid in sulphuric acid, gives gradually a brown, then a golden, and finally a blue color.

Another very important reaction of phenol consists in its behavior when treated with bromine water. A watery solution of phenol, with a freshly prepared solution of bromine water, gives a bulky, white, precipitate, even in solutions up to 1 : 40000 or 50000. Upon this reaction a quantitative method of determining phenol is based.

The reaction of phenol with formaldehyde and its different modifications are of very great interest and the resulting products will be dealt with in further articles under "Condensation" and "Synthetic Resinous Products" (Class G).

CONDENSATION

Condensation is a special form of the many synthetical reactions applied in organic chemistry.

The simplest form of a condensation takes place when two molecules of the same or different organic compounds unite under proper conditions by means of carbon linkings, whereby one or more molecules of water are eliminated, and a more complicated compound of a higher carbon content is formed. This newly formed body is termed a condensation product, and it is usually

impossible to decompose it into its original components. Generally some condensing agents, as for instance H_2SO_4, $ZnCl_2$, anhydrides, caustic alkalies, ammonia and its derivatives, which are capable of splitting off H_2O, are applied, thus causing the condensation reaction whereby one of the substances loses oxygen, whereas the other one splits off hydrogen as shown in the equation.

$$\underset{\text{Acetaldehyde}}{CH_3CHO}+\underset{\text{Acetaldehyde}}{CH_3CHO}=\underset{\text{Crotonaldehyde}}{CH_3CH:CH.CHO}+\underset{\text{Water}}{H_2O}$$

Sometimes, however, more than two molecules of the same or different substances may combine, with separation of H_2O.

$$\underset{\text{Benzaldehyde}}{C_6H_5CHO}+2\underset{\text{Aniline}}{C_6H_5NH_2}=\underset{\text{Diamidotriphenylmethan}}{C_6H_5CH\ (C_6H_4NH_2)_2}+\underset{\text{Water}}{H_2O}$$

In other condensations, elimination of HCl; NH_3 or even CO_2 may take place. To the latter reaction belongs the well-known process of producing Ketones by heating calcium salts of organic acids.

$$\underset{\text{Calcium Acetate}}{(CH_3\ COO)_2\ Ca}=\underset{\text{Acetone}}{CH_3\ COCH_3}+\underset{\text{Calcium Carbonate}}{CaCo_3}$$

Also by means of an oxydation a condensation reaction may be produced.

Phenols containing one OH group, for instance, when treated with ferric chloride, lose one atom of hydrogen and turn into higher phenols containing two OH groups and the double amount of carbon atoms:

$$2\underset{\text{Naphthol}}{C_{10}H_7OH}+2FeCl_3=\underset{\text{Dinaphthol}}{C_{20}H_{12}\ (OH)_2}+2HCl+2FeCl_2$$

Aldehydes and especially ketones are very liable to condensation reactions, whereby complicated compounds of very high molecular weights are frequently produced.

The same process we probably encounter, according to more recent discoveries, in the formation of resins in

plant life, the latter being very likely condensation products of formaldehyde with phenol.

THE HOT MOLDED ORGANIC MATERIALS (Class "A")

The ingredients of sealing wax and of this class of molded insulation have not varied from their earliest history.

The binders play the important part in this class of materials, the principal ingredient of which once was, and still ought to be, shellac.

Owing, however, to the steady increase in the price of shellac, it has been replaced almost entirely by cheaper materials, such as damar gum, rosin, asphalts, pitches and cheap resins.

Two methods are employed to combine these binders with such fillers as wood pulp, magnesia, lime, sand and asbestos, and such coloring matters as lamp black, various metallic or earth pigments, and organic dye stuffs.

First: The organic binders are placed in a heated mixing machine in which they are melted, and when in a molten condition, the binders are gradually added and mixed. The mixture is then removed in a hot plastic condition and rolled into sheets. These sheets are broken into convenient sizes, softened on steam tables and then placed in heated dies, pressed, cooled therein, and removed in a finished condition. The dies in this method are the open dies, described more fully under the chapter "Moulds and Dies."

In the second method employed in molding this class of products the organic binding materials are dis-

solved in proper solvents and the mass mixed with the filler in about the same kind of mixing machines as in the first method, except that no heat is employed. The material is removed from the mixing machine and on exposure to the air the solvents evaporate, leaving an intimate, uniform, mixture. This mass having become hard is ground to powder. The powder is then placed in heated dies in which it remains under pressure until it is melted, it is then cooled and removed from the die in a finished condition.

The dies used in this method are called "closed dies." This type of die is explained under the chapter "Molds and Dies."

Manufacturers of products of this class vary the minor details of the processes of manufacture, but all follow one of the two above mentioned fundamental methods.

Materials produced by either of these two methods differ but little in their properties. The second method, however, allows the incorporation of more filling material.

In the first method, the amount of filler which can be added is restricted, for if too much is used, the plastic nature of the mix is diminished and the material will not flow properly in the die.

The second method is free from this difficulty, for the material, being in a powdered form, can be readily introduced into the dies, which are of such design that the material cannot escape, but is forced to all parts of the die, and intimately welded together by the pressure.

The higher the proportion of binding material, and the more finely reduced the filler, the more plastic the mix will be, and the cleaner the appearance of the finished piece.

On the other hand, the higher the percentage of filler, especially when the filler is inorganic, the less plastic the mix will be and the poorer the appearance of the finished piece, but it will be less subject to the softening influence of heat, which constitutes a serious defect in materials of this class.

The composition of material of this class varies over a wide range, and the characteristics differ accordingly.

If the binder is entirely free from rosin or cheap gums, these products are very stable and their life is long. Unfortunately, however, the general trend for the past ten years has been to substitute rosin and dammar gum for shellac, which, especially in case of rosin, due to its well-known unstable qualities, will cause the compound to deteriorate rapidly under climatic exposure.

However, rosin is extensively used because of its low price, and the advantage it possesses of being rapidly melted and molded at comparatively low temperatures, in which respect it is the best substitute for shellac. All other substitutes have the objection of requiring higher temperature to melt, and not being so readily molded in dies.

It should be stated here that a certain variety of bitumens or asphalts melt very easily, but pieces made with such binders do not withstand any great temperature. In some cases, these products have been known to soften under the rays of the sun.

Materials of this class, when proper ingredients are employed, are practically non-hygroscopic, and moisture has no detrimental effect on their physical or chemical properties. It might be mentioned that products of this class, containing a great excess of fillers, for instance, asbestos fibre, will absorb more or less water, but these products, if properly made, even though they

absorb moisture to a certain extent, are sufficiently impervious under ordinary weather conditions for use for ordinary voltages, if they contain no rosin.

As none of the ingredients undergo any chemical change in the processes employed in the manufacture of these products, it is perfectly obvious that they will always soften at the temperature to which they are subjected in their mixing or molding processes. For instance, articles made with shellac, which softens at 80° C., will not withstand temperatures above this point. Rosins, which stand less, and materials made with soft bitumens, will soften in the sun's rays in hot weather. This is particularly true if the binders are in great excess in the mixture.

Such materials can be made so that they will withstand a momentary flame, and if not subjected to heat for too long a time, they will not readily soften, but they will invariably fail as soon as a continuously applied temperature reaches the melting point of the binding medium.

The insulating properties of this class of materials vary very materially. For instance, one specimen .001 inch thick may be punctured by 500 volts, while another specimen of the same thickness will be punctured by 50 volts.

The reason for this great difference lies in the wide variation in the composition of materials of similar appearance. The higher the percentage of organic binder, the better the insulating properties; the lower the percentage of binder, and the higher the percentage of filler, the poorer the insulating qualities will be. The more intimate the mixture between the filler and binder and the higher the pressure under which it is molded in the proper plastic condition, the less porous the product

will be, and consequently the higher its resistance to puncture.

The use of such materials for electrical insulation has somewhat diminished because these products do not withstand heat. They are liable to become inflamed by the short circuiting of wires carrying low voltages, and the Underwriters are steadily becoming more and more strict and are specifying materials of greater heat-resisting qualities.

The field, however, for this class of materials is still very large, and from the following illustrations, it will be seen to what a wide range of uses in the electrical art, these materials are still adapted.

Several concerns, both here and abroad, have, after long study and experiments, been able to produce pieces suitable for high tension insulation, and they claim considerable advantages for these substances over porcelain for high tension work. The discussion of insulation for high tension work is not within the province of this work, and therefore these special shellac compounds will not be treated here in detail. It may be said in passing, however, that this material has been commercially produced for this purpose, although the bulk of insulation of this kind is still made in porcelain.

COLD MOLDED ORGANIC MATERIALS (Class "B")

Molded insulating products of this class are similar in appearance to those of Class "A," and chemical analysis would show that they are composed of an organic binder and an inorganic filler, as are most of the materials of that class. The usual binders employed in the manufacture of these products are the asphalts, and the fillers are such inorganic substances as asbestos, silica, and magnesia, organic fillers being but rarely employed. In color they are universally black, due to the asphalts used in their composition.

A fundamental and very important difference between materials of this class and those of Class "A" is that the incorporation of the filler with the binder and the subsequent molding is not done under heat, but the binding medium is brought into solution by suitable solvents, and the filler thoroughly mixed with the liquid or semi-liquid binders in a cold condition. This semi-plastic mixture is then molded in cold dies, care being required to have the material sufficiently soft to mold properly. The pressed pieces are then subjected to a drying process, during which the solvents are drawn off or enter into composition with the other constituents, whereby a hard, solid and durable substance is obtained.

The making of materials by this process presents some manufacturing disadvantages, for instance, during the drying process, they are subject to a slight shrink-

age, unlike articles molded of the materials of Classes "A" and "G," which come from the dies in a finished condition. For this reason a slight variation of the finished pieces, from exact dimensions, should always be allowed as is customary with users of porcelain. However, as the shrinkage incident to the drying of these materials is only one-eighth that which takes place in the firing of the ceramic products (porcelain) they can be depended upon for greater degree of accuracy than those of Class "D."

In fact, the art of manufacturing these cold molded inorganic materials has undergone such development during the last ten years as to make it entirely practicable to mold such materials with sufficient accuracy to fully meet the demands of commercial conditions.

The products of this class are not manufactured in such a great variety of grades as those of Class "A" and while the insulating properties of different materials of this class vary, their use is, as yet, restricted to the manufacture of parts for low tension insulation.

One of the chief advantages of these products and one to which is due their wide favor among electrical engineers is that they are exceedingly stable, and once manufactured will not soften under heat, and moisture has little effect upon their physical or electrical properties.

In Class "A" it is the binder which is always the important part, whereas in materials of Class "B" it is the filler—the asbestos fibre which imparts to the product its main advantages, the binder performing the functions of cementing and waterproofing media.

THE COLD MOLDED INORGANIC MATERIALS (Class "C")

Materials of this class differ from those of Class "A" and "B" in the characteristic principle of the use of an inorganic binder, while in Classes "A" and "B" an organic binding media is used.

The binders of this class are compounds of silica, alumina, lime and magnesia, or usually Portland Cement, while the filler is usually asbestos fibre.

The use of hydraulic cements for such purposes was retarded for years, due to its poor plasticity, but during the last ten years great progress has been made in this direction, and today they are extensively used as binders for materials of this class.

Its use as a binder is, however, a critical one, and not only must the cement be selected with great care to assure its fitness, but in the manufacturing operation several well defined steps are necessary in order to obtain a properly plastic material.

The main difficulties consist in the proper incorporation of reagents to develop the plasticity of the mixture without injury to same. Their action is yet not thoroughly understood, but possibly it is of a catalytic nature.

Broadly speaking, the binder is incorporated with the filler in the presence of water, and the moist mixture is pressed in a cold state in dies under heavy pressure, whereby the excess of water is eliminated and the molded pieces are given a consistency which permits them to

be removed from the dies. The hardening of the mouldings afterwards is effected by the action of the hydraulic binders in a similar way to the hardening of Portland Cement.

Such insulating products, owing to the inorganic nature of both binder and fillers, are unaffected by heat and the electric arc, and by various treatments they are rendered non-absorbent to moisture.

The appearance of materials of this class is not as attractive as that of materials of Classes "A," "B," "G" and "E," but their physical properties, owing to the nature of the inorganic binder, possess the peculiar advantages of rather improving in quality with age, as do all materials of concrete nature containing hydraulic binding media.

Both binders and fillers play an equally important part in the compounding, and the mechanical properties of the finished articles depend to a considerable degree on the structure of the asbestos fibre used as a filler.

CERAMICS
(Class "D")

This class is usually known under the broad term of "CERAMICS," the most familiar representative being porcelain. Other materials of this class are glass, fused silica, fused clay and roasted soapstone (Lavite).

PORCELAIN

The so-called hard porcelain is of the most importance for electrical uses. Hard porcelain comprises a large percentage of China Clay, to which is added quartz and feldspar or other flux, and sometimes small percentages of gypsum, chalk, etc. The quality of the China Clay used, is of first importance, for on this is dependent the plasticity of the mixture, which enables it to be molded in the desired forms, and also, to a large extent, the final hardness, strength and heat-resisting qualities of the product. The proportions in which these ingredients are used vary with different manufacturers, each of whom has developed a formula by which proper results can be obtained. Great care is necessary in each step of the manufacturing process, from the mixing of the ingredients to the annealing of the products as they come from the kiln. A slight relaxation of care at any one stage is more likely to endanger the quality of porcelain than of other molded insulating products.

In the manufacture of porcelain the various raw

materials in proper proportion are mixed in rotating drums in the form of a slurry, it being, of course, essential that the ingredients be in a finely divided form, and in the case of the China Clay, free from impurities. The excess water is removed by various means, and the wet mass is stored for some time, during which the homogeneity and plasticity are improved. In some plants this plastic cake is directly molded in dies, while in others it is dried, re-ground, mixed with water and molded. In pressing porcelain pieces, more especially when the walls are thin, great care is necessary. The articles, after drying, are burned in kilns at various temperatures up to 2,000-deg. C. The temperatures and methods of firing vary with different manufacturers, and great skill has been developed at this stage.

Owing to the considerable shrinkage of porcelain in the firing process, it is evident that wide practical knowledge of the behavior of various shapes in the kiln is essential in order that the final product shall be of the form and dimensions originally designed, and it is worthy of remark that this art has undergone such development as to enable the production of parts of very complicated design.

LAVA COMPOSITION

In making articles of this substance, the waste from the cutting up of slate is used. The powdered material is mixed with solutions of sodium silicate. The mass is dried, powdered, and molded in dies under pressure after the addition of sufficient water. The molded articles are then fired at high temperatures, and after cooling are again treated with the alkaline silicate solution and

fired again. This operation is repeated until absorption of the alkaline silicate ceases.

The finished products are very hard and tough and are somewhat similar to porcelain. They resist sudden changes in heat better than porcelain and for certain insulating purposes are, therefore, more desirable. Their great shrinkage during firing and the consequent difficulty in obtaining accuracy in the finished molded form. is their principal draw-back.

Special grades of lava compositions are made for resistance insulators and for this purpose have no superior.

RUBBER COMPOUNDS
(Class "E")

Among the various materials employed in the manufacture of Molded Insulation, rubber is the only product which in itself, without the admixture of a filling or strengthening medium, presents all the desirable qualities of an insulator, combined with the necessary mechanical strength and other requisite physical properties. Its toughness, elasticity and flexibility are not even nearly approached by any other insulating substance known today. Therefore, its qualifications as a binder for organic or inorganic fillers are also unsurpassed. The only reason why this excellent insulation as well as binder has been gradually replaced is its high price and inability to stand continuous temperatures of 100-deg. C., or over, even when properly compounded with such heat-resisting fillers as asbestos.

In the chapter on raw materials will be found a full description of the preparation of caoutchouc, and rubber and their compounding.

ORGANIC PLASTICS
(Class "F")
CELLULOID

While molded insulating parts are not made of this material to any notable extent, it is nevertheless employed for this purpose, especially where ornamental appearance is a considerable factor. It is a good insulator and can be molded with greater facility than perhaps any other material, and were it not for its poor heat-resisting qualities, it would be extensively employed for electrical insulating purposes.

Celluloid is a solid solution of more or less nitrated pure cellulose in camphor, and is pressed, after evaporating the various solvents in the form of sheets, plates, blocks or rods. In this stage it is a transparent, elastic, flexible mass which can be given any desired color by the introduction of dye stuffs or pigments.

Before going into the details of the manufacture of celluloid, the manner of making nitro-cellulose and the general method of making celluloid will be briefly outlined.

Nitrocelluloses are celluloses which contain the nitro group NO_2, and are known as Di, Tri, etc., up to hexamitrocellulose or even higher ones, according to their content of the nitro groups. In celluloid manufacture, as a rule, the higher nitrated celluloses are used, commonly known as "gun cotton" which contain about 9% to 12% nitrogen.

They are obtained by treating very pure cellulose, like tissue paper, purified cotton, flax or hemp fibres, with a mixture of concentrated nitric acid and more or less concentrated sulphuric acid.

The proportions of the two acids may be varied considerably. For instance, three volumes of nitric acid Spec. Grav. 1.517, to one of sulf. acid Spec. Grav. 1.84, or three volumes of sulf. acid Spec. Grav. 1.845, to one of nitric acid 1.5, are used.

The proportions of the paper and of the acid mixtures vary considerably. Furthermore, a different time of reaction has to be allowed according to different conditions. The space in this book is too limited to go into these complicated details.

The nitrocellulose, purified by washing with cold water until perfectly free of acid, is then treated with a weak sodium carbonate solution at ordinary temperature, and the latter again removed by washing with cold water. The pure material is ground to pulp, the water extracted in centrifuges, and after having been dried at about 40-deg. C. it is mixed with a solution of camphor in alcohol.

The proportion of camphor and nitro-cellulose varies from 20% to 30% of camphor and 70% to 80% of nitrocellulose.

The alcoholic camphor mixture is passed between rollers heated to 105-deg. C. This process is carried on until a homogeneous and plastic mass results. These rolled celluloid sheets are then pressed into solid blocks, free of air bubbles, under a pressure of about 3,500-lbs. per square inch.

A few of the special methods employed in the manufacture of celluloid may be mentioned.

1. The so-called Hyatt process consists in dissolving

gun-cotton in molten camphor. Satin paper is sprayed with a mixture of two parts nitric acid and five parts sulphuric acid as it is unwound from a roll, whereby the greater part of the paper is converted into nitro-cellulose or pyroxylin. The acid is now entirely removed by washing with water, and the plastic mass is subjected to considerable pressure and dried. The lumps, after being broken up again and drained in a hydroextractor, are ground and finally mixed with the camphor in the proportion of one part of camphor to two parts of pyroxylin, though other proportions also give good results.

The well mixed mass is then pressed in order to expel any watery constituents still present; and furthermore, to bring the particles of camphor and pyroxylin into still more intimate contact to facilitate the solvent action of the former.

The dried and pressed mass is placed in molds and given the desired shape by the application of hydraulic pressure, under heat. On leaving the press, the celluloid is hard, but remains plastic and can be re-softened by warmth, or by placing it in boiling water.

2. Cold process of preparing celluloid.

In operating this process, the greatest care must be taken on account of the great inflammability and low boiling point (35-deg. C) of the ether which is used to dissolve the camphor; thorough ventilation of the factory rooms is very essential. The proportions used in this method are 50 pounds of nitro-cellulose, suffused with a mixture of 100-parts of ether. After the ether has been slowly evaporated, the mixture finally becomes a transparent, sticky, gelatinous mass, which is rolled between a pair of superimposed calendering rollers until it is plastic. On exposure to the air, the rolled viscid

sheets attain a certain hardness. They are then warmed and subjected to powerful pressure. This is important as the valuable properties of celluloid are improved in proportion to the pressure applied. To obtain good celluloid by the cold ether process it is also highly important that the raw material should be dry and perfectly free from acid, otherwise the celluloid will be cloudy.

In another process, the gun cotton after being pulped with water, is treated with a mixture of camphor and woodspirit (methylalcohol). The principle, however, is identical with that of the other process.

Pure celluloid is nearly colorless. In thin sheets it is as clear as common glass. It is very elastic, transparent, tough, and hard. Celluloid has a faint smell of camphor which becomes stronger when the mass is rubbed. It is electrified by friction. Heated sufficiently it becomes plastic and can be molded into any shape desired. On heating up to 140-deg. C., celluloid loses its color and transparency, and at about 50-deg. higher decomposes with the liberation of pungent, readily inflammable vapors.

Since celluloid softens in warm water the molding process is greatly facilitated by this behavior. Celluloid ignites only when brought in direct contact with flame and then burns with a smoky flame giving off an odor of camphor. On blowing out the flame the mass continues to flow and to give off thick fumes of camphor. This is a clear proof that celluloid is not a chemical combination of camphor and gun cotton, since it is characteristic of chemical reactions that the substances entering into combination cease to exist independently in the compound.

Celluloid is insoluble in water and though not im-

mediately attacked by concentrated sulphuric acid it gradually dissolves therein. A small piece entirely disappears in about 36 hours. Concentrated nitric and boiling caustic alkali also gradually dissolve it.

The specific gravity of celluloid varies according to the degree of pressure to which it has been subjected in the manufacture, the mean being 1.50.

Celluloid is very extensively used as a substitute for horn, tortoise shell, coral, malachite, lapis, marble, ebony, amber, caoutchouc, ebonite, etc. As a matter of fact, there is hardly any natural product which has not been imitated in celluloid.

Continuous experimenting and research is carried on in attempts to render celluloid less inflammable and to make it more useful as an electrical insulator.

ALBUMINOIDS—CASEIN

The purpose of the creation of these products was to obtain a substitute for celluloid which would not have the poor heat-proof characteristics of the latter. Products of extraordinarily fine nature have been developed, based on treating curdled milk with acetic acid or other reagents to throw down the casein.

A plastic mass is thus obtained to which organic or inorganic filling material is usually added. It is then molded in heated dies in a manner similar to the materials of Class "A."

Such products would not be stable under the action of moisture, but treatment with formaldehyde renders this mass less susceptible to humidity and other climatic influences.

These compounds can be easily worked with tools and stand temperatures of 20-deg. to 30-deg. higher than the

celluloid compounds. They char upon the application of heat without inflaming.

This material will, however, not stand the continued action of water as well as the celluloid compounds, but its higher heat-resisting and non-inflammable qualities render it valuable for many purposes.

As insulating products, these materials are not to be considered of great importance, their use being practically confined to the manufacture of molded articles for domestic use.

In all such compounds, the casein plays the important part, but numerous inventions have lately been developed to partly substitute the casein by organic or synthetic resinous binding products.

While these newer compounds may improve the qualities of this product, they have not yet produced materials of any great value for electrical molded insulating parts, notwithstanding their excellent plastic qualities.

SYNTHETIC RESINOUS MATERIALS
(Class "G")

In discussing the hot molded organic products (Class "A"), attention has been called to their most serious defect, namely; their low-melting point due to this characteristic of their chief binding medium, namely shellac.

The replacing of shellac by a binding medium having all the valuable qualities of this material without its serious defect of softening at comparatively low temperatures, has been highly desirable.

The serious interference with the proper and reliable operation of electrical apparatus and machinery caused by the softening or inflaming of the molded insulating parts made of materials of Class "A" has caused electrical engineers and designers to eagerly seek a more heat and fire resisting product.

The materials of Class "G," the Phenol-Formaldehyde products, have all the advantages of the hot molded organic materials (Class "A") and in addition possess heat-resisting qualities to a high degree and are well suited for every purpose to which these Class "A" materials are adapted. Unfortunately, their high manufacturing cost restricts their use very largely to articles of electrical insulation, the cost of which is of little consideration or a small item in the cost of the apparatus.

The peculiar heat-resisting and dielectric properties of these products are due to the binder, a synthetic

resinous substance obtained by the chemical reaction of phenol on formaldehyde.

As early as 1872, such artificial resins were obtained and at various times since considerable literature has been published and much research work undertaken in endeavors to produce such synthetic resinous substances on a practical commercial basis.

It seems strange that while today the high heat-resisting properties of these products are recognized as a vital characteristic advantage, the earlier investigators and inventors had nothing further in mind than to produce synthetically what nature had already given in shellac.

The research work done along this line consisted in combining phenol with formaldehyde by means of heat, with or without the presence of acid or alkaline agents, to act as catalysers, causing the mixture to condense.

The water is thus eliminated by evaporation, or it is otherwise separated from the viscous, condensation product.

Various proportions of the constituent materials, the kind of catalytic agents used, the length of time of heating and temperatures, all affect the character of the resulting compound, which is first a viscous liquid and then a hard, fusible solid, which on further heating, polymerizes into an infusible product.

Up to about six years ago, such synthetic resinous bodies were not valued for their heat-resisting qualities, that is, their characteristic of becoming an infusible substance upon the further application of heat; and they were of no great value as shellac substitutes in the literal significance of the term substitute, because of their higher cost. Consequently, they were not much heard of outside the laboratory and in patent literature.

The brittleness of the final hard product was another reason why their usefulness was so long unrecognized, but by incorporating fibrous substances with these synthetic resinous materials a product was obtained. Molded articles made from this equal or surpass in strength every known insulating material, with the exception of rubber products.

While the production of these phenol-formaldehyde compounds has reached a state of perfection which may reasonably be termed a scientific as well as a commercial success, very little is known of their exact chemical composition. Attempts have been made to show a definite chemical reaction and a definite atomic combination between the constituent elements, but the various authors of such formulae and theories disagree to such an extent that we must conclude that the exact nature of this substance has not yet been determined, and await further investigation to give us more conclusive scientific information.

The commercial molded insulating products of this class and the methods employed to incorporate with them the organic or inorganic fibrous filling materials, will now be discussed.

One manner in which this is accomplished is by heating the mass obtained by the condensation process only to a point where it is plastic when hot, but hard when cold. In this stage of its production, it is ground to powder and mixed in suitable proportions with the fillers. This mixture is placed in heated dies and held under pressure until the binder is first rendered plastic and then transformed into the hard infusible state. The dies are then cooled sufficiently to permit the removal of the molded pieces. Such pieces leave the dies in a finished state exactly as the shellac compounds do.

Generally, these pieces on the application of a flame, give off a carbolic acid odor. Some manufacturers try to overcome this by subjecting the pieces to a further exposure to heat, to drive off these odors.

Another method of producing molded articles of this class is to mix the viscous, condensation mass directly with the fillers, heating the mixture just to a sufficient degree to make it hard when cold, but plastic when hot, grinding it to a powder and subjecting this powder to the same treatment as described above.

It is therefore seen that the mixing in of the filling materials and the molding of the compound must be done before the binder reaches its infusible state.

There are at the present day a great many patents covering the manufacture of these synthetic binders, but they are all based on the principle here mentioned.

Two distinct products of the above type are now made for electrical purposes with considerable success.

While the manufacturers claim marked differences in their products, the characteristics of the binders are the same, and any difference which exists is dependent upon the character of the fillers.

One product is obtained by using a filler which is chiefly an organic material (wood pulp), while the other employs asbestos fibre.

The products made with wood pulp have the advantage of being more easily molded and leaving the dies with a more elegant appearance, but while those made with asbestos fibre are in this respect somewhat inferior, they resist heat better, noticeably the electric arc.

The manufacturers using wood pulp claim that their product is heat-proof to 175-deg. C.; the manufacturers using asbestos claim 250-deg. C. The difference in the heat-resisting properties of these two products is in no

way dependent on the binders, it depends entirely on the filler.

In the case of the product made with the organic filler, the comparatively low heat-proof quality is due to the nature of the filling material, while the breakdown point of the material made with the asbestos filler is the limit of heat-resistance of the binder.

Both products are claimed to be unaffected by moisture or water.

Exposure of several years has confirmed this; but this class of synthetic binders is of too recent introduction to make a definite statement as to their water-resisting qualities in comparison with such organic binders as rubber.

The writer has made various tests on both these products, and has found that both materials, if properly manufactured, are practically unaffected by moisture; but the wood-pulp material after an immersion of several months in water seemed to be slightly more affected than the materials with the inorganic filler.

As in the case of the shellac compounds, the more inorganic filler used the more such material will withstand arcing; the more binder used, the easier these pieces are molded and the less they absorb moisture.

The insulating qualities of these phenol-formaldehyde products are very high, and they have found a ready market. Another advantage they possess is that they can be molded into any shape with absolute accuracy.

FIBRE
(Class "H")

Under this heading we will discuss those materials which have been known under this name from the earliest times, and also a newer fibre product which is cemented by means of resinous binders.

VULCANIZED FIBRE

This material is prepared by treating vegetable fibres (paper) with chloride of zinc or other metallic chlorides, alkaline compounds, and sulphuric acid.

The fibres are thus partly dissolved and brought to a somewhat sticky (glutinous) condition in which they are subjected to high pressure, generally in the form of sheets of various thickness.

The action of the various active chemical compounds used in the treatment of the fibre, and the pressure afterwards used, render the product homogeneous and tough; but as the rinsing out of the excess of the various chemicals is never complete, the remaining portions are the source of the troubles so often experienced in the use of this material for electrical insulating purposes.

Vulcanized fibre is unaffected by organic solvents. It is very tough and its property of being easily worked with tools has made it an extensively used product in electrical work.

It does not burn immediately on exposure to a flame or arc, but will char and carry the flame after a few moments exposure to heat exceeding 175-deg. C.

It is unstable under atmospheric exposure, and warps and deforms readily. This inability to resist water is the most serious drawback to this product.

FIBRE TREATED WITH RESINOUS BINDERS

This class of materials has come into favor lately with electrical engineers, for it has the excellent properties of fibre without the drawbacks of the latter's unstable nature.

These materials are manufactured by agglomerating fibres by means of dissolved resinous substances (such as shellac or copal solutions) or by phenol formaldehyde binders.

The so agglomerated fibrous sheets are then subjected to pressure under heat in a manner similar to the manufacture of built-up mica, the heat causing the binder to melt and thus to cement the fibrous layers firmly together.

This class of material, when made with synthetic resinous binders, is very stable and exhibits high dielectric and heat-proof qualities and good mechanical properties.

When the binders are of a natural resinous nature, the heat-resisting properties are governed by the softening point of the binder.

MOLDED MICA
(Class "I")

These products are made by splitting mica into thin laminae which are cemented together by means of resinous binders.

The so built up sheets or forms are afterwards subjected to pressure and heat, the heat melting the binding materials, thus forming a compact product. According to the nature and proportion of the binders used, these mica compositions can be made more or less heat-resisting, but obviously to such a degree only as the binding material will withstand.

All attempts so far to cement mica in sheets or in powdered form by means of an inorganic binder have failed, but should these attempts ever prove successful, a very broad field will be opened up for this excellent insulating material.

PROPERTIES

LIFE

The first requirement of a molded insulating part is that it be stable. That is, it must retain its shape and physical and electrical characteristics under service. It must not deform nor disintegrate, and it must maintain its dielectric strength.

Neither heat, cold, nor sudden temperature changes, the action of the electrical current, nor chemical actions induced by this current, must exert any deleterious effect upon it.

No material in use today perfectly fulfills all of these conditions.

The materials which most nearly meet these requirements are the ceramics, Class "D."

The inorganic compounds, "Class "C," are also very stable. This class possesses the peculiar characteristic of improving with age and exposure to air and weather, in which important particular it differs from porcelain, (which is inert under these conditions) and all other forms of molded insulating material which deteriorate more or less with age.

The bituminous, cold molded materials, Class "B," while they do not meet these requirements as fully as the two foregoing classes, are still very durable; for, during the higher temperature treatment to which they are sub-

jected after molding, the unstable elements are either driven off or forced into stable combinations and rendered inert.

The rubber compounds, Class "E": Rubber when properly compounded is very stable, but unfortunately the increasingly high cost of the better grades of this valuable substance offers great temptation to the manufacturer and practically all commercial rubber is adulterated with low grade resinous gums and other substitutes which greatly reduce its life and consequently its usefulness as a material for molded insulating parts.

The synthetic resinous compounds form a new class of peculiar products which have been in use for a comparatively short period and definite judgment must be withheld until time has demonstrated their value. The writer has seen this material in service both outdoors and indoors, where it has seemed to fulfil all the claims of its adherents, but knows also of cases where in outdoor work it has not given satisfaction, although this may have been due to faulty or careless manufacture and not to any inherent defect in the material.

It is the writer's opinion that the very broad claims made for it are not extravagant, and that it will before long be so fully developed as to wholly justify itself.

The shellac compounds—Class "A"—suffer under the same disadvantages as the rubber materials. High grade shellac compounds are quite stable, but as shellac is comparatively expensive, most of the materials of this class are adulterated, usually with rosin, which in consequence of its unstable nature, and very low melting point, very seriously affects the value of materials of this type.

Class "F"—The celluloid compounds are stable at

low temperatures, but due to their poor heat-resisting qualities their use is restricted.

The albuminoids are quite stable under certain conditions, but in consequence of their very hygroscopic nature they are unsuited for molded insulation.

Class "H" Fibre—Ordinary Fibre is falling into disrepute because its shape changes with varying atmospheric conditions.

On the other hand, the new class of hardened vegetable fibre is of a stable nature. It is practically unaffected by climatic conditions, although its use is not advised for outdoor insulating work. Owing to the hygroscopic nature of organic fibres, a certain amount of moisture is absorbed. It will, however, retain its shape.

MOLDING

Another fundamental requirement of a molded insulating material is that it may be readily formed into such shapes as the requirements of the particular use to which it is to be put demand.

The methods employed in the manufacture of molded insulation can be broadly separated into two fundamental classes—the cold molding process and the hot molding process.

In the first class the material is molded in cold dies and subjected to a further process after pressing.

In the second class, the material is first rendered plastic by heat and then molded in hot dies, the articles being removed from the dies when cold in a finished state without subsequent treatment.

The first method is employed for the materials of Classes "B," "C" and "G."

The second method is employed for the materials of Classes "A," "E," "F" and "G."

The materials made up by the second method can be molded into almost any shape that may be required and with great accuracy, as these materials when molded are perfect plastics, and leave the dies in a finished condition.

The fact that the materials made by the first method have to be treated after pressing has been responsible for a great deal of inaccuracy of dimensions in cold molded insulating parts. The materials used in the first method are, generally speaking, not so easily molded into complicated shapes, nor with such a nice degree of accuracy, but considerable progress has been made in the last few years in this particular branch of insulating manufacture, and parts can now be obtained which meet all reasonable requirements.

Attention should be called here to the peculiarity of the materials of Class "B" not being suitable for molding into flat plates or parts of large size. On the other hand, the materials of Class "C," are particularly adaptable for such purposes.

Materials in Class "D" are liable to a shrinkage as high as 15% in their subsequent treatment (firing). This makes it difficult to control with accuracy the dimensions of the finished piece, and it has become a custom of the trade using porcelain to allow a variation of .015 per inch or more in parts made of this material.

Some manufacturers of materials of Classes "B" and "C" claim that they can mold true to size, while others require the acceptance of a variation not exceeding .010 of an inch, especially in pieces of complicated form, but it would be advisable for designers of parts to be made of cold molded materials to bear in mind that all such

materials are apt to vary slightly from the drawings and not to originate such combinations of insulating material and metallic parts as may be unfavorably affected by a variation of a few thousandths of an inch.

For pieces in which no variations can be allowed and where extreme accuracy and perfect finish are required, materials of classes "A," "E," or "G" are to be preferred, provided other conditions permit their use.

Practically all molded insulating materials except those of Class "D" can be manufactured with metal parts imbedded in them.

The practice of molding in metal parts has become very extensive and has been a large factor in the successful introduction of molded insulation, as it has eliminated the process of inserting these parts in the shop, which process is often expensive and unsatisfactory.

On the other hand, such excellent results have been obtained by this process of incorporating metallic inserts in molded parts that some designers have become over enthusiastic in regard to this feature, and expect too much of the molded insulation manufacturers, especially in pieces of complicated design, and they would do well when designing new combinations to consult with the manufacturer from whom they expect to purchase before going too far with their specifications and drawings.

The materials of Class "H" are not strictly molded materials, but are furnished in sheets, tubes and rods.

PUNCTURE TEST

The insulating value of molded materials is usually determined by puncture tests.

As this treatise will not discuss insulation for high tension work, and has only to consider voltages below one thousand, the materials of all the different classes herein enumerated can be considered as chosen for the particular conditions, and the thickness of the insulating part is designed to correspond to the insulating properties of the material selected.

The insulating properties of porcelain or other ceramics vary according to the properties of the chemical components of the product.

The insulating properties of the cold molded inorganic materials Class "C" vary not only according to their composition, but to the treatment they receive in the various stages of their manufacture.

Class "B"—In the cold molded organic materials, the mixture again plays an important part, but the amount of pressure and conditions under which the piece is subjected to this pressure determine to a very great extent the nature and value of these products.

Classes "A" and "E"—The Shellac and Rubber Compounds. The variation in the insulating properties of these materials depends almost entirely on the compounding of the products.

The amount of pressure employed in molding is not of great importance, provided sufficient pressure is used to thoroughly weld the ingredients.

Class "F"—The organic plastics are uniformly of high dielectric strength. They are dense, homogeneous masses composed of ingredients of high insulating value and contain no fillers to render them porous, or to reduce by their lower insulating value the point at which these materials puncture.

Class "G"—The synthetic resinous materials vary in dielectric strength somewhat according to the nature of the synthetic binder. These binders as produced today do not differ greatly from each other in respect to their dielectric strength, hence, the value of materials made with them as the important ingredient, depends principally upon the nature of the fillers entering into their manufacture.

Class "H"—Fibre like the organic plastics is of a homogeneous nature and its insulating value doe not vary greatly, but is somewhat dependent upon the physical treatment and seasoning it undergoes in its manufacture.

The newer materials of this class, i.e., those formed of thin sheets impregnated by and cemented together with organic or synthetic resinous materials, depend very largely on the latter for their insulating value, but they are also affected to a considerable degree by the temperature and pressure to which they are subjected during their manufacture.

Class "I"—The high insulating value of molded mica depends almost entirely on the great dielectric strength of the mica, the other ingredients being employed merely to cement and hold the mica flakes together.

MECHANICAL STRENGTH

One quality of prime importance which a molded insulating piece must possess is mechanical strength.

Years ago when porcelain, fibre, hard rubber and wood were the standard insulating materials, fibre was generally employed for those parts which were subjected to unusual stress.

As long as fibre, wood, or a good quality of hard rubber was used, metal parts were often embedded in, or fastened to the insulating parts by drilling and then threading and screwing, or by simply punching and riveting.

The strength, toughness and resilient properties of those materials were such that these methods of manufacture and assembling were not objectionable. Designing and manufacturing departments became accustomed to this treatment, and when the various new insulating materials were introduced they frequently entirely overlooked the fact that these newer substances might not possess the same mechanical characteristics as those with which they were familiar; and the old processes of drilling, riveting, etc. were attempted with unsatisfactory results. The usual consequence then was that these materials were condemned by the workmen because they were different from those to which they had become accustomed.

This condition of affairs, more than anything else, retarded the introduction of molded insulating parts, and gave manufacturers of these parts untold trouble and expense, until it was demonstrated, that their products possessed advantages sufficiently valuable to more than compensate for the apparent defect of requiring somewhat different treatment and handling.

Fibre is still quite extensively employed in many shops, particularly for experimental work, and where on account of the small number of pieces required, the expense of a die is a considerable factor in the cost per piece. However, even the newer fibre materials cannot compete with molded insulating parts if used in large quantities, and materials of this type are destined to constantly decrease in popularity, except for experimental

and special work or where great flexibility, resiliency and mechanical strength are of first importance.

The molded insulation products which have come nearest to fibre for strength and toughness are those of Class "E," the rubber compounds, and more lately those of Class "G," the synthetic resinous materials. Some of the materials of both of these classes possess excellent mechanical strength and are equal, if not superior, in this respect to any.

Porcelain is one of the very best insulating materials we have, and wherever its brittleness is not a serious drawback, its use is recommended, particularly on account of its low cost. Contrary to general opinion, its tensile strength is high, but unfortunately its elasticity is very low and consequently it will not withstand shock, and should not be employed where it will be subjected to sudden strains or excessive vibration.

Materials, which have successfully competed with and to a large measure have already replaced porcelain, are those of Classes "B" and "C," the organic and inorganic cold molded materials, and parts made of these materials when properly designed and used, give excellent results because they are less brittle and more resilient.

Before the introduction of the cold molded materials "B" and "C," the hot molded organic materials of class "A" seemed destined to surpass porcelain for a great variety of purposes, on account of their superior mechanical strength, but owing to their poor heat-resisting properties, they themselves have been in turn superseded by the cold molded materials because of the better heat-resisting qualities of the latter, there being as a rule no characteristic difference in the mechanical strength of materials of Classes "A" and "B." The

inorganic materials of Class "C" possess a greater mechanical strength than the products of Classes "A" and "B," although they are not quite as strong as those of Classes "E" and "G."

The materials of Class "F" are fairly strong, but they are seldom chosen for this reason. They are usually employed because of their ornamental appearance.

No matter what insulating material is selected, manufacturers should always bear in mind that it is advisable to design electrical apparatus so that the insulating parts may fulfil their primary function as an insulator, without being subjected to undue mechanical stress, and that this stress should be put upon parts and materials which by their very nature, are better able to sustain it.

WEATHERPROOF QUALITIES

The ability to resist the effects of moisture is a very essential requirement of a molded insulating material.

No matter how good in all other respects a molded insulating material may be, if it is affected by moisture to such a degree that it either deforms, disintegrates or loses its dielectric properties to such an extent as to cause short circuit, it is useless.

No insulating material is entirely unaffected by moisture or water. A material is said to be "non-hygroscopic" when it is affected by water only to so slight a degree that this defect can be safely disregarded.

Moisture has no effect on materials of Class "D," although in their unglazed condition they absorb water to a certain extent, but this is entirely overcome by the glazing process. Porcelain may, therefore, be considered as the best material in this regard.

Class "C" (Inorganic cold molded materials). Moisture has no deteriorating effect on this class of products, but in their untreated condition, they absorb moisture to such an extent as to make them unsuited for purposes where they come in continuous contact with water. In their treated condition, however, the absorption of moisture is reduced to a point where it does not materially affect their insulating properties, and they have been used with success for the last 10 years for outdoor insulating purposes.

Class "B"—In the organic cold molded materials, the filler is so thoroughly saturated with the waterproof binder that the absorption of moisture is so slight as to be negligible, and these materials may properly be classified as waterproof. The writer knows of many instances where these products have been in continuous outdoor service for more than ten years without showing the slightest deterioration.

Class "A" (The organic hot molded materials). When high class gums are employed in the manufacture of the binder, these materials are absolutely waterproof.

Class "E"—The hard rubber compounds are thoroughly waterproof, although when made for high heat-resistance and containing an excess of asbestos fibre, they will absorb water to some degree. This, however, has no serious effect, except that it lowers somewhat the dielectric strength.

Class "G"—The synthetic resinous products possess the same excellent waterproof qualities as the properly made materials of Class "A"—at least, the five years during which these materials have been upon the market has so far justified such an opinion.

Class "F"—The celluloid products are absolutely waterproof, while the casein compositions are not suited to use where they will be exposed to moisture.

Class "H"—Fibre has fallen into disrepute because of its very hygroscopic nature, but the newer class of this material is expected to gain favor because it does not exhibit this disadvantage.

HEATPROOF QUALITIES

During the last ten years operating conditions and the development in all electrical lines have made increased demands upon the heatproof qualities of electrical insulating parts, and the underwriters requirements in this particular, have become stricter and stricter, until today the heat-resisting properties of an electrical insulating part is one of the most important factors in the choice of such materials.

The term fireproof is frequently used in describing molded electrical insulation, but in a strict scientific sense nothing is fireproof, and in a commercial or practical sense, insulation is rarely required to be fireproof. The term heat-resistant or heatproof is employed to those materials which do not soften readily or at all under excessive heat; or which do not burn or char upon contact with flame or the electric arc, or will cease to burn as soon as the burning agent is withdrawn.

The most heatproof materials obtainable today are the Ceramics, the best known and most widely used product of this class being porcelain, and whenever conditions permit its use, it is to be recommended. It is, however, liable to crack under sudden temperature

changes of wide range. Under such conditions, the lavite products are preferable, as they will withstand sudden and even violent variations of temperature somewhat better.

Where, for mechanical or other reasons, porcelain is not suitable, the choice lies between the organic cold molded materials, the inorganic cold molded materials or the synthetic resinous products. All these materials may be considered heatproof in that they will not soften or be otherwise disadvantageously affected when continuously subjected to a temperature of 100-deg. C., which is the usual maximum working temperature of electrical machinery.

The hot molded organic materials (Class "A"), the rubber compounds (Class "E") and the organic plastics (Class "F") are all seriously affected by the continuous application of such a temperature.

Of the three Classes "B," "C" and "G," the synthetic resinous materials (Class "G") are the strongest, and because of their excellent molding qualities and their neat appearance, they are to be preferred where cost is a secondary consideration. These materials will withstand continuously a temperature of from 150-deg. C. to 250-deg. C., depending on the nature and percentage of the filling medium employed.

For most purposes, however, such as in the construction of lighting fixtures and electrical apparatus of all kinds where the cost of the insulating parts is not of minor or negligible importance, and heatproof qualities are essential, the cold molded materials (Classes "B" and "C") are more suitable.

It is not advisable to employ the organic cold molded materials (Class "B") for continuous temperatures above 300-deg. C., while the inorganic cold molded materials

(Class "C") are perfectly reliable under the continuous action of temperatures up to 900 deg. C.

If, in the manufacture of materials of Classes "B" and "G," the ingredients are proportioned so that an inorganic filler is thoroughly and intimately intermingled with a proper minimum quantity of the organic binder, products can be obtained upon which the electric arc has but little effect.

In general, however, it is advisable to manufacture arc deflectors and all parts which are subjected to constant arcing and similar conditions, of the inorganic cold molded materials, as their inorganic nature precludes all possibility of softening or charring.

While these materials are unaffected by arcing or momentary temperatures of 1500-deg. C., they should be used with caution for service where they will be subjected to continuous temperatures of over 900-deg. C., as may be the case in resistance insulators, for instance. Although materials of this type Class "C" are in use today for such purposes and are apparently giving satisfaction, nevertheless, it must be borne in mind that very high temperatures above 900-deg. C. sustained for too long a time are apt to split up the water of constitution, and thereby affect the nature of these materials. But under these conditions, some of the constituents will fuse, and this fusion, if only partial, will offset the loss of mechanical strength, due to the dissociation of the water.

However, it has been amply demonstrated that the inorganic cold molded materials are inert under continuous temperatures of nearly 900-deg. C., sustained for long periods of time.

The materials of Class "H," fibre, should not be employed where they will be subjected to the influences

of the arc or continuous temperatures above 150-deg. C. The vulcanized products of this class are apt to warp at 100-deg. C.

The organic hot molded materials (Class "A") will not withstand the electric arc, and they should not be exposed to continuous temperatures above 80-deg. C., owing to the low melting point of the binders employed.

The heat-resisting properties of built-up mica (Class "I") are limited by the melting point of the shellac, and unless the sheets of mica are confined and positioned by some mechanical means, these products will not stand temperatures in excess of 100-deg. C.

RESISTANCE TO CHEMICAL ACTION

Materials intended to withstand the continued action of acids or alkalies must be carefully chosen. While most insulating compounds will resist these actions to a greater or lesser degree, few of them are proof against acids or alkalies for any great period of time.

The only materials which can be safely employed for this purpose are those of Class "D," the Ceramics, and to a certain extent the products of Class "E," the especially compounded hard rubber materials. All other materials must be regarded with suspicion for such work.

MACHINING OF MOLDED PIECES

One of the chief advantages of molded insulation is that it can be delivered to the user in an absolutely finished state, and it is not intended to be worked by means of tools. However, with the exception of Class "D," all these materials can be worked with more or

less satisfaction, although it is not advisable to attempt it, but rather to design the parts so that no machining will be necessary.

Class "H," however, may be worked with considerable facility and this is the chief reason why these materials continue to be used to a limited extent for almost every electrical application.

COLOR AND APPEARANCE

The color and appearance of molded insulating parts, while not usually of primary importance, are sometimes deciding factors.

The color of the various insulating materials is generally dependent upon the colors of their principal ingredients, and only in special instances do coloring materials play an important part.

Materials of Class "D," for instance, are usually white, but in some cases the glazing is done in various colors.

In materials of Class "B" the color is usually black and depends upon the ingredient substances which cannot be changed. This material can be furnished with a very high finish.

In materials of Class "C" the color is usually white or black, but these materials can be furnished in various colors. The materials of this class present a smooth, close-grained, attractive, appearance, but do not take a high polish.

The materials of Class "A" are naturally black or brown, but by the introduction of coloring matter, they can be made in a wide range of colors. Materials of this class usually leave the die with a high polish.

The natural color of materials of Class "G" is a reddish brown, but they are very often made in black and can be produced in various colors by the addition of coloring matter. Their appearance is the same as is Class "A."

Class "E"—The asbestos-rubber compounds are usually furnished in their natural gray-brown and the hard rubber in black color, but they can be made in a variety of colors. Most of the hard rubber compounds take a very high polish.

The materials of Class "F" are particularly adapted to coloring and can be furnished in a very wide range of colors and finishes, and for this reason are occassionally used on account of their appearance.

Materials of Class "H" are furnished in a variety of colors, but are usually gray, black or red.

Where an ornamental appearance is essential and a high polish is required, designers should remember that the quality of the surface of the products of Classes "A," "E," "F" and "G" is due to the method of manufacture and the character of the material, and that they leave the die with a high polish, or that same can be obtained by a simple buffing process.

On the other hand, the products of Classes "B" and "C" while they come from the molds with a smooth and continuous surface, present a flat and lusterless appearance, and in order to give them a high polish they must be ground on fine abrasive wheels or carborundum or like material, and then buffed. It is self-evident that such treatment cannot be satisfactorily applied to parts having small or intricate projections and depressions, or to parts of irregular and complicated shape.

MOLDS AND DIES

In the molded insulating trade these terms are synonymous.

Most electrical engineers are familiar with some methods employed in the construction and operation of the molds in general use in the manufacture of insulating parts. The molds play a very vital part in such manufacture and are often the cause of serious difficulty to the manufacturer, and consequent misunderstanding between him and his customer. The author will as briefly and comprehensively as possible sketch the more important factors in their construction and use, to enable the user, through a better understanding of their operation, to avoid those elements of design which tend to complicate manufacturing operations. This knowledge will facilitate the selection of forms for his insulating parts which, while rendering them no less effective for his purposes, will enable the manufacturer to produce pieces of minimum cost, maximum efficiency and neat appearance.

Frequently designers, when bringing out new forms, insist on having dies of the cheapest construction made in order to get out a few sample pieces. This results in serious trouble for the manufacturer, and dissatisfaction for the customer until a proper mold is substituted.

This is especially true when the form of the piece is in any way complicated by holes, projections, or irregular surfaces, and unless the molds are made of the very

best steel, and all the parts come together with a perfect fit, the molded pieces will be more or less misshapen and have burrs or fins on their edges. These imperfections are a frequent cause of complaint. It is, therefore, very important to have the molds of such quality that they will wear for as long a time as possible without producing pieces with these defects. All dies will eventually wear out, and the only remedy then is to replace the worn parts or make complete new dies.

The form of the piece and the character of the material to be molded play an important part in this particular, and a mold may show more wear after a run of 10,000 pieces of one material than it would after turning out 100,000 pieces of another material.

TYPES OF MOLDS OR DIES USED IN THE MANUFACTURE OF MOLDED INSULATION

There are two different classes of dies in general use. They are known as "OPEN DIES" and "CLOSED DIES."

The term "OPEN" is applied to that class of dies or molds which are composed essentially of two flat pieces in one or both of which a recess is provided to hold the material to be molded. In operation, these plates come together at a cutting edge which chops off the excess of material which has been squeezed out of the recess containing the molded part.

The term "CLOSED" is applied to that class of dies or molds which are composed essentially of a plunger and a box. In operation, just enough material to form the part is placed in the box; the plunger then enters the box and forces the material to all parts of the mold.

In practice these dies are made with two plungers; the upper plunger, which, generally speaking, does the compressing; and the lower plunger, which forms the bottom of the mold, and which, after the piece is formed, raises to push the piece from the mold.

Both "OPEN" and "CLOSED" dies are in general use for the manufacture of hot molded materials, while only closed dies are employed in the manufacture of cold molded products.

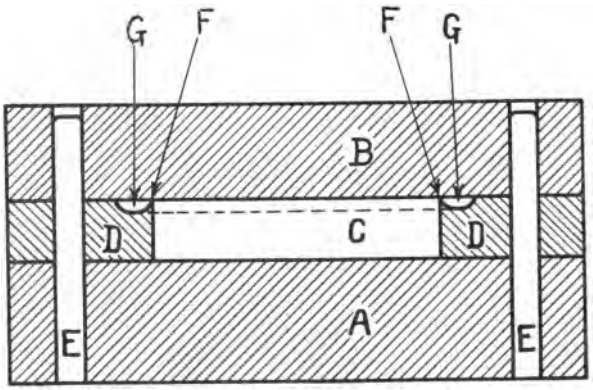


FIG. 1

Figure I represents an open die, such as is used in the manufacture of materials of Classes "A," "E," "F" and "G," when such materials are prepared in sheet or cake form and placed between the compressing plates in a warm or plastic condition.

This die, which is intended to produce a disc or short cylinder having parallel sides, is made in three parts, the Bottom Plate "A," to which is screwed or otherwise fastened the middle plate "D," containing

the opening "C," in which the piece is to be formed, and the top Plate "B," which closes the die, guided by the pins "E."

In operation the die is heated; an excess of material is placed in the cavity "C;" the die is closed; the Cutting Edge "F" cuts off the surplus material, which has been squeezed into the depression "G" formed to receive it. The die is then cooled and opened; the plate "D" is released from the plate "A," and the finished piece is pushed out by the fingers or other means.

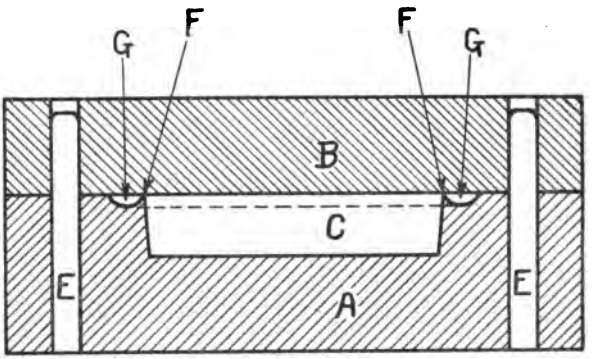


FIG. 2

If the sides of the piece instead of being straight are tapered, a simpler form of mold shown in Figure 2 can be used.

In this case, the die can be made in two parts, and after the piece is formed and the die cooled, the piece. due to its tapered form and the shrinkage incidental to cooling, can be readily removed by simply inverting the die and rapping it till the piece falls out.

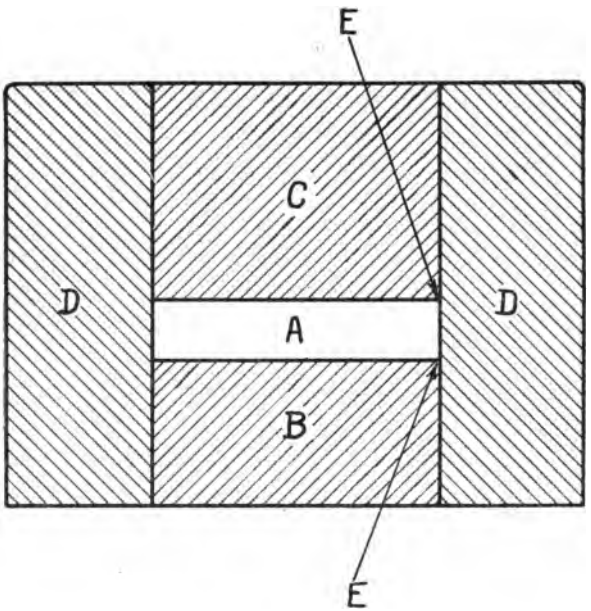


FIG. 3

In Figure 3 is shown a closed die, such as is used in the molding of materials in a heated state and comprises a Box "D," an Upper Piston "C," and a Lower Piston "B," having between them a cavity "A" in which the piece is formed. It will be noticed that the upper piston is longer than the lower one.

In operation the Box "D," with the Lower Piston "B" is placed upon a heated press table and the material to be pressed is placed in the Cavity "A," see Figure 4. Before pressing, this material occupies a volume considerably greater than the volume of the finished piece, and for this reason the Top Piston must be longer than the Bottom Piston, since it must travel into

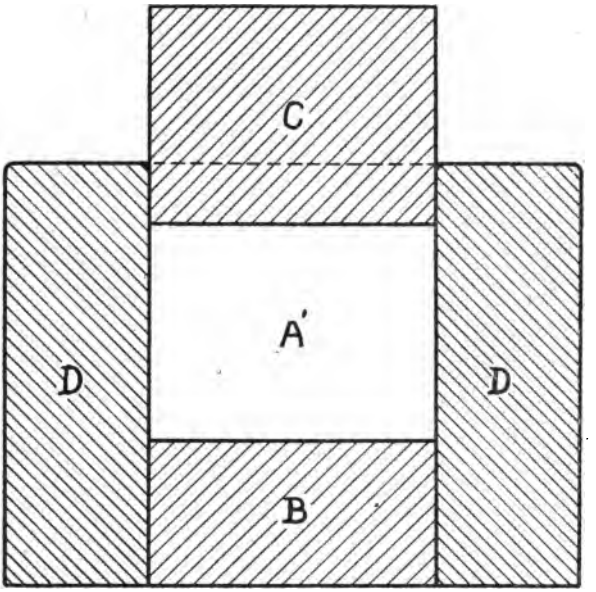


FIG. 4

the box a sufficient distance to compress the material to be molded to the required density.

The Top Piston is now placed in the Box and the Upper Platen of the press, which is also heated, is brought down by hydraulic or other pressure on the Piston "C" until its top surface is flush with the top of the Box "D." The die is now held between the heated plates of the press until the material in the Cavity "A" is melted. The steam is then shut off and cold water is run through the plates of the press until the material in Cavity "A" is sufficiently cooled to render it hard enough to permit of its removal from the mold.

Sometimes the walls of the Box "D" are provided with channels through which the steam and water are run to expedite the molding process.

In practice, steam is kept on the press plates and molds just a sufficient length of time to properly melt the material to be molded, and the water is run through only long enough to permit of the ready removal of the finished piece, as the time consumed in these operations determines the output of the press, and so directly affects the cost of the piece. In making parts, such as bushings and other pieces having holes in them, which are formed by pins incorporated in the mold, the piece must be removed from the die before the shrinkage has progressed to a point where the material would seize upon the pins and thus prevent its easy removal from the mold.

It is necessary that the Pistons "B" and "C" should be a nice fit in the Box "D" in order that the pieces may come from the dies without burrs, which would otherwise form at "E," Figure 3. This is particularly true in the case of materials of Classes "A," "E," "F" and "G," which come from the molds in a finished and highly polished condition, and are not subjected to any further finishing treatment.

It is obvious, however, that constant use will eventually cause the box and plunger to wear, when the mold will necessarily produce defective pieces.

This type of die may be used for molding any class of material, but is usually employed in the hot molding of such materials as those of Classes "A," "E," "F" and "G."

Figure 5 shows a die of the type used in the manufacture of cold molded materials, such as those of Classes "B," "C" and "D." This die embodies the same gen-

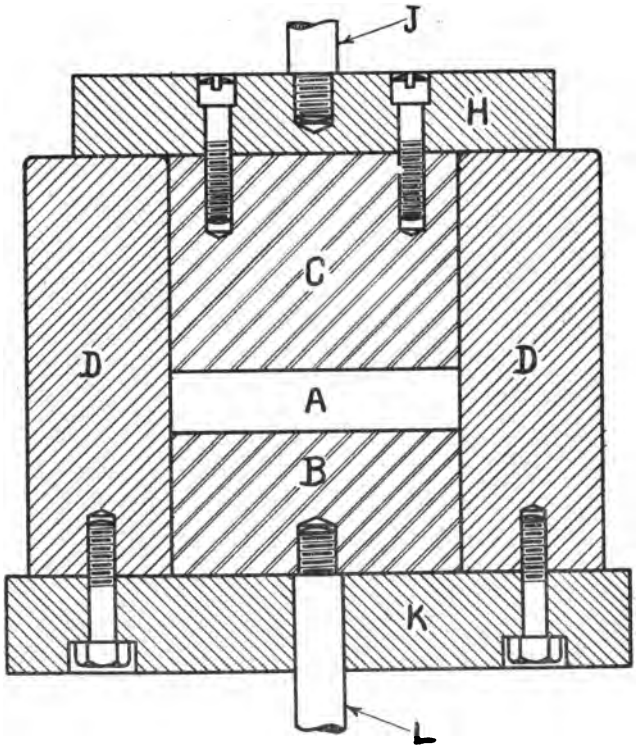


FIG. 5

eral principles as those shown in Figure 3, but in this case, the Upper Piston "C" is attached to the Plate "H," which in turn is attached to the upper platen of the press. The Box "D" is attached to a Plate "K," which is fastened to the bed of the press and the lower piston is operated by means of the Throw-out Rod "L" connected to the lower plunger of the press.

The operation is as follows:

The mold is filled with the material to be pressed as in the case of Figure 3, and the piece is compressed

in a similar manner. At this point the similarity ceases. After the piece is pressed, the Upper Piston "C" is withdrawn from the mold and the Lower Piston "B" is raised by the Throw-out Rod "L," and by this means the piece is expelled from the mold. The Piston "B" now descends to its normal position at the bottom of the mold and it is then ready for re-filling without having to undergo any heating or cooling operations.

When dies of this type are employed, the materials are either weighed or measured beforehand, and just sufficient is introduced into the die to form the piece.

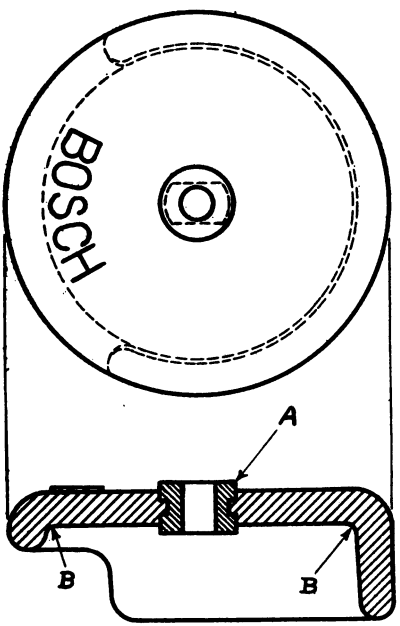


FIG. 6

Figure 6 shows a molded piece with a metallic insert "A" molded in. Such pieces can be easily produced in

materials of Classess "A," "B," "C," "E," "F" and "G." However, if absolute accuracy, together with a highly polished piece is required only Classes "A," "E," "F" and "G" can be considered. Class "B" could be advantageously molded into this shape, but a slight variation must be tolerated and only the exterior surface can be polished. Class "C" could be molded accurately, but it would be necessary to increase the radius at "B" as much as possible.

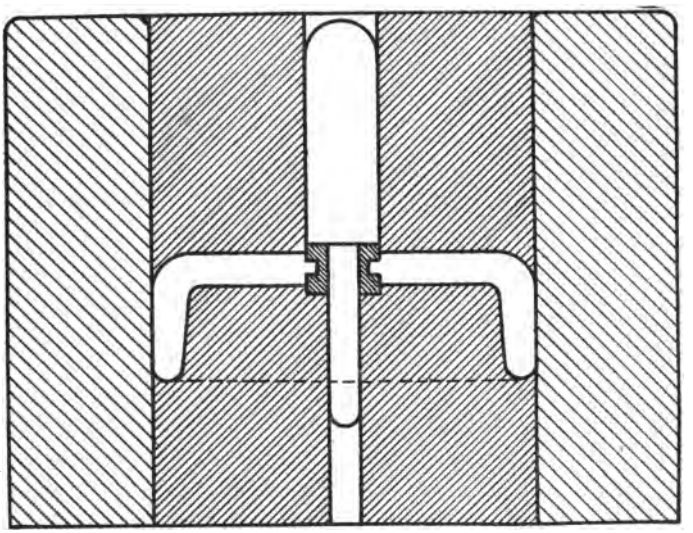


FIG. 7

Figure 7 shows the design of the mold from which this piece is produced, and is here represented to illustrate the manner in which inserts are molded into the materials. These inserts should be provided either with

a knurled or some other rough and irregular surface so that they may be firmly gripped by the material.

Another point of interest is the production of letters or figures on molded pieces.

On materials such as those of Classes "A," "E," "F" and "G," where the pieces come from the molds in a polished condition, no difficulty is experienced in producing raised letters. However, if such materials as those of Classes "B" and "C" are used, where the pressed pieces do not come from the molds in a finished condition, but must be hardened, ground, and polished, raised lettering cannot be used, as the grinding and polishing of the surface would destroy them. Therefore, it is essential in all cases where pieces are to be made of materials in Classes "B" and "C," that the designer employ some other means to incorporate the lettering on his pieces.

An excellent method and one which has become a standard for use in connection with these materials is to recess a portion of the surface, leaving the letters raised and flush with the main surface, so that the tops of letters receive the same polish as the rest of the surface.

Metal inserts are never molded in pieces made of the ceramic materials. Openings or recesses are molded, into which the metal parts are inserted and held in place by riveting or other mechanical means. Usually sealing wax or some other form of cement is used to fill the recesses, covering the screw heads or nuts to prevent the exposure of live parts.

Figure 8 shows a typical cross section of a molded insulating box or cover, and illustrates very nicely some of those elements of design constituting a part of that unwelcome legacy which comes to the molded insulation manufacturer from his predecessors who worked with

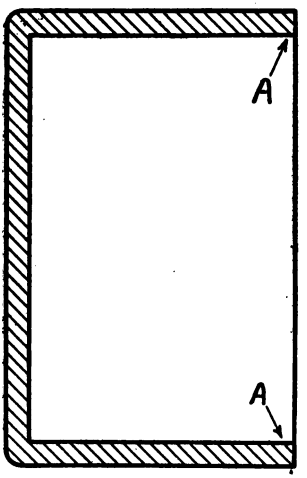


FIG. 8

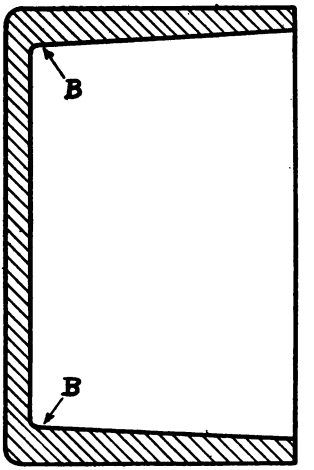


FIG. 9

materials of a very different nature.

This cross section shows a cover or box having thin walls and sharp interior corners. In other words, a typical metal box or cover, which offers no difficulty whatever to the metal stamper, but which is not well adapted to meet the requirements of the modern molded insulating materials; it is a good, if very simple, example of the trouble designers often make for themselves and the molded insulation manufacturer by failing to bear in mind that the characteristics of modern materials differ from those formerly in common use. If, as often happens, the apparatus, of which this cover is to form a part has been made, or the component metal parts which compose it are already under construction or ordered from some other sources before the molded insulation manufacturer is consulted, the designer of such a cover may find himself in trouble and be fortunate

if he has put himself to no greater inconvenience than to greatly restrict the number of materials from which this part can be made.

The design of this cover, Figure 8, is entirely unsuited for manufacture from materials of Classes "B," "C" and "D," which are among the best materials from which to make such parts as switch and fuse box covers, owing to their high heat-resisting qualities, but the straight thin sides of the box practically make it impossible to form this piece of these materials, and it would be very difficult to properly mold the thin parallel sides, as the material would not be compactly pressed at the top of the sides, Point "A," unless a complicated mold were employed, which would exert the necessary extra pressure.

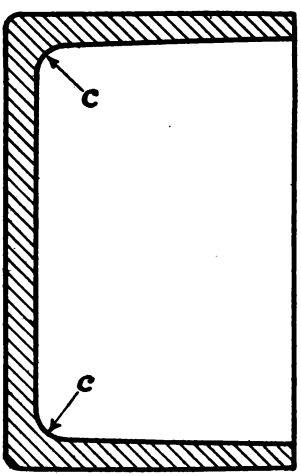


FIG. 10

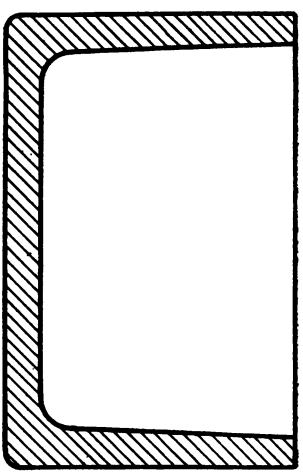


FIG. 11

Should there be room inside the box to thicken the side walls particularly at their base point "B"

Figure 9, and so give the sides a taper or draw, the design would be improved. Even this added thickness is not sufficient in most cases, as it would be of great advantage to put as large a radius as possible in the corners "C," as is shown in Figure 10.

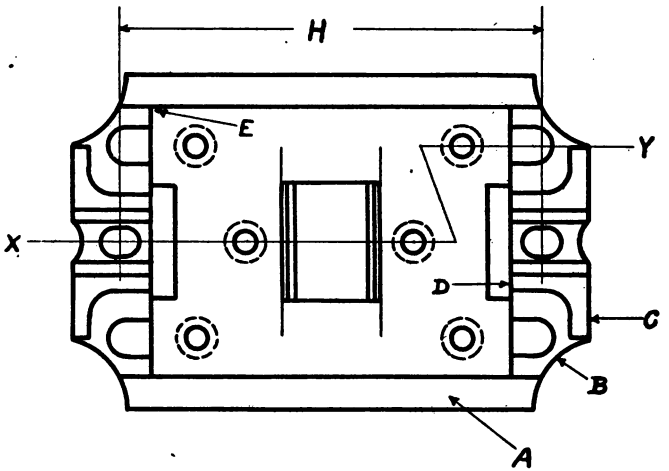
Figure 11 shows a cover having the proper thickness of walls, with the necessary draw or taper to the inside, and a generous fillet or curve in the corners to make it an ideal design for the proper flowing and molding of the materials of Classes "B," "C" and "D." This form is equally well suited to materials of Classes "A," "E," "F" and "G," although the free flowing qualities of these materials do not make it imperative that the piece be designed in this manner.

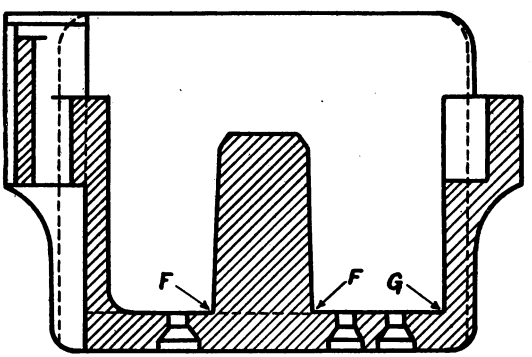
Figure 12 shows a receptacle box of rather intricate form. Formerly such pieces were made exclusively in porcelain, but are now also extensively manufactured in the cold molded materials of Classes "B" and "C."

The synthetic resinous materials of Class "G" are splendidly adapted to producing pieces of this character, but they are very rarely used because of their high cost in comparison with Classes "B," "C" and "D."

In a previous illustration, particular stress has been laid on the desirability of designing such pieces with thick walls and ample radius at the bottom, particularly when made of materials in Classes "B" and "C." Too much emphasis cannot be laid on these points.

Figure 12 shows that it is possible to produce pieces of this design in these materials, but it is not accomplished without some difficulty, and in some cases it requires a very complicated mold. It also becomes necessary to sacrifice the mechanical strength in order to have a mixture of material which has the viscosity necessary to meet the molding requirements.





SECTION X-Y

FIG. 12

A much more satisfactory design for both the customer and manufacturer would have resulted if walls "A," "B," "C" and "D" were made somewhat thicker;

also by the addition of a radius at Points "E," "F" and "G."

In molding pieces of this character in porcelain, it has been the custom to allow for a variation in the distance "H" by making the holes about 1/32" larger than the diameter of the screws which fit in these holes.

Although the manufacturers of materials of Class "B" generally claim that they can mold such pieces more accurately than those made in porcelain, it would be advisable for the designer not to figure on absolute accuracy in a piece of this nature, if he intends to have them made of this material. He should allow for a few thousandths of an inch variation.

Designers frequently assert that they are limited as to space, both inside and outside, of such parts, but, with a better understanding of the fundamental requirements of the molding art, and a fuller realization of the difficulties they make for the insulation manufacturer, and the consequent higher cost and poorer quality of the pieces they obtain, they can originate pieces better adapted to molding in the materials they require.

By giving a little more consideration to the molded insulating parts before the design of the apparatus, in which those parts are to be incorporated, has become irrevocably fixed, designers would materially help themselves as well as the insulating manufacturer.

Figures 13 and 14 show two insulated knurls of different design, serving the same purpose, and the molds for producing them.

Figure 13 shows the original or incorrect design and Figure 14 the same piece altered to facilitate the molding, increase the production, improve the appearance of the piece, and to make the mold much easier and less complicated to manufacture and handle.

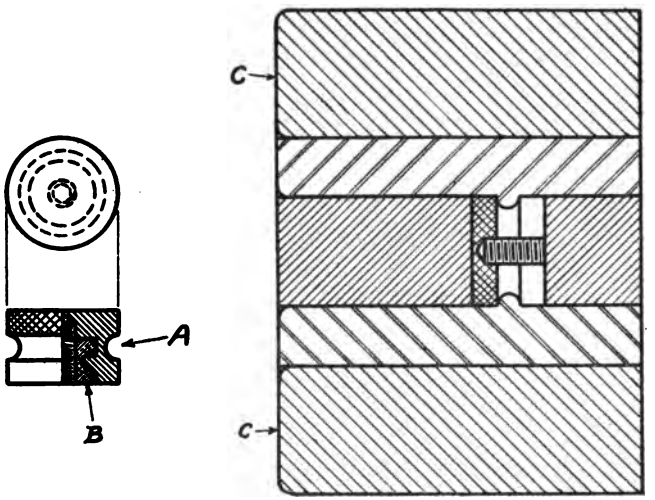


FIG. 13

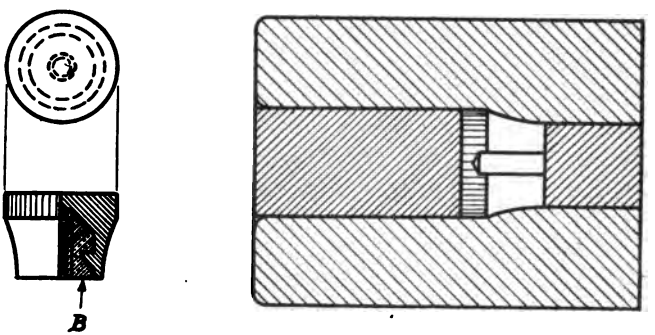


FIG. 14

The piece shown in Figure 13 presents numerous difficulties. The groove "A" on the side and also this type of knurling makes it absolutely necessary for the piece to be surrounded by a number of loose parts which must be removed from the Box "C" in order

to free the piece from the same. This can readily be seen from the section shown. At the junction of these loose parts, a finn or burr will be formed which must be removed, thus increasing the cost of manufacture and affecting the appearance of the piece.

Another bad feature of this design is the thread molded in the material above the metal insert "B." As all molded insulating materials shrink more or less, the threads in the molded material will be smaller than those in the insert.

On the other hand, the design as shown in Figure 14 is much simpler and less complicated. The groove on the side is entirely eliminated and the style of knurling is changed from braided to straight, thus making it possible to push the piece from the mold by merely pressing it from the bottom towards the top. This, of course, does away with the loose parts and eliminates all burrs and produces a perfectly clean, smooth, and neat appearing piece.

It will also be noticed in this figure that the insert "B" has been lengthened to accommodate the full depth of thread which would otherwise be partly molded in the material. The sloping sides or pointed appearance on the end is to allow the material to flow off and around it instead of packing tightly and crushing on the top as it would do if it were flat.

Therefore, the design as shown in Figure 14 is strongly recommended whenever it is possible for two important reasons:

First: The lower cost of production.

Second: The freedom from burrs which will form at the junction of the split portions of the mold made necessary by the groove on the side, and the use of this type of knurling.

These conditions apply not only to insulated knurls, but to any pieces of similar design or construction.

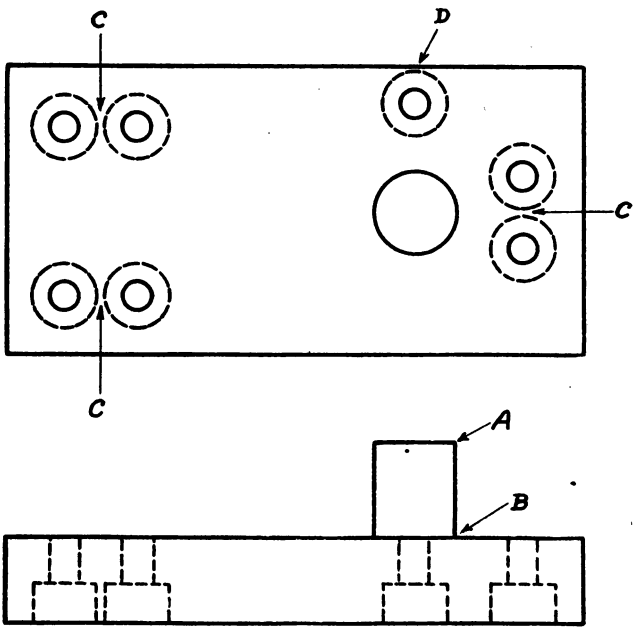


FIG. 15

Figure 15 represents a molded base with a projection "A" and numerous counterbored holes. A piece of this design is readily molded of the hot molded materials "A," "E," "F" and "G," also of the ceramic materials, Class "D." It can also be molded of materials of Classes "B" and "C," if certain changes in design are made.

In the first place the flowing qualities of these materials, Classes "B" and "C," make it difficult to mold such shapes as projection "A," unless molds of com-

plicated construction are resorted to. Such pieces can be made perfectly practical for cold molding by the introduction of two simple modifications.

First by the addition of a radius around the base, as is shown at "B" in Figure 16, and secondly by giving a slight draw or taper to the sides, which is also shown in this same figure.

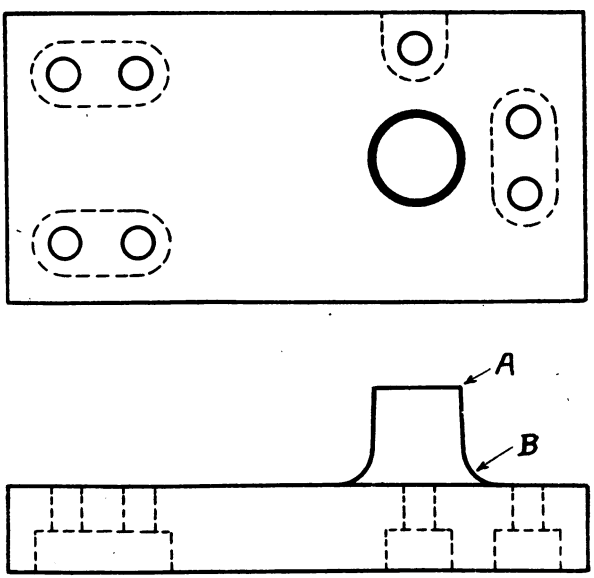


FIG. 16

With these modifications, such a projection can be readily molded true in form, neat in appearance, and with the proper mechanical strength.

It is possible to mold pieces with this projection exactly as is shown in Figure 15, but the modifications suggested are simply to increase production and to reduce the cost.

Another point is the shape of the counterbores. In Figure 15, two counterbores are shown which are so close together as to leave a very thin separating wall, as at point "C." At point "D" there is also a very thin wall produced between a single counterbore and the side of the piece. When wood and fibre were extensively used and insulating pieces were machined from blocks and sheets, this was a logical design, but it is not now well suited to the peculiarities of modern insulating mediums.

In order to adapt this piece to the present requirements of cold molded materials, it would be advisable to eliminate these thin walls by cutting them away, as is shown in Figure 16, thus making one elongated counterbore, and opening the other to the outside of the piece.

If, however, it be necessary to have a barrier of this kind separating these counterbores owing to electrical requirements, the designer should place these holes far enough apart and away from the edge of the insulating piece so as to allow a wall of ample thickness.

In all cases, the depth of the counterbores should be no greater than the requirements of the piece, and ample draw or taper should be allowed on the sides of the same in order to allow the easy removal of the piece from the surface of the pistons in the mold.

All holes should be made as large as convenient for their purpose, so that the pins in the mold which form them may be as rugged as possible.

Figure 17 is a typical piece of molded insulation used as a strain insulator in overhead line construction and shows how the insulating material is molded around the metal parts.

The hot molded materials of Classes "A," "E"

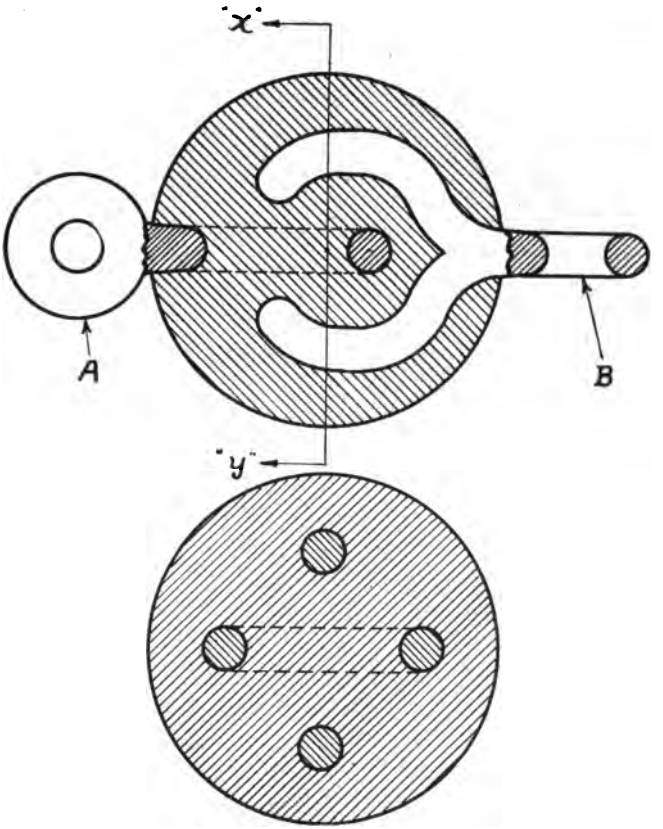


FIG. 17

and "G" are well suited to the manufacture of such parts, and while formerly the rubber compounds of Class "E" were extensively used, to-day the materials of Class "A" practically monopolize this field, chiefly on account of their lower cost.

For this latter reason the synthetic resinous products of Class "G" have not come in use for such purposes,

their cost being too high, although the properties of this material seem to indicate that it would stand up well as an insulator under the severe climatic conditions to which such insulators are exposed.

The cold molded materials of Classes "B" and "C" are used for the manufacture of such pieces, but to a limited extent. As they do not possess the necessary plasticity to be molded as easily as the hot molded products, the molding of such parts causes difficulties owing to the high pressure required to obtain perfect molded pieces.

The hot molded materials of Classes "A," "E" and "G" are readily molded with comparatively little pressure while in a hot plastic condition around the two metal parts which are held in position at the outer ends by the die.

In case of molding materials of less plastic nature, such as Classes "B" and "C," around these two metal parts, such materials do not flow easily around the metal inserts, but have to be forced around them by means of high pressure. These inserts, held in position only by the die at their extremities "A" and "B," and having no central support, are apt to be distorted, rendering the finished piece imperfect and useless for service.

The Figure 18 illustrates a magneto insulator as is commonly used for automobile work. Formerly such parts were made either of materials of the rubber compounds of Class "E" or else of special grade materials of the organic hot molded products of Class "A."

As the magnetos are usually placed near the hot engines, and the insulating parts come in contact with hot oils and gasoline vapors, considerable trouble was previously experienced with the materials above men-

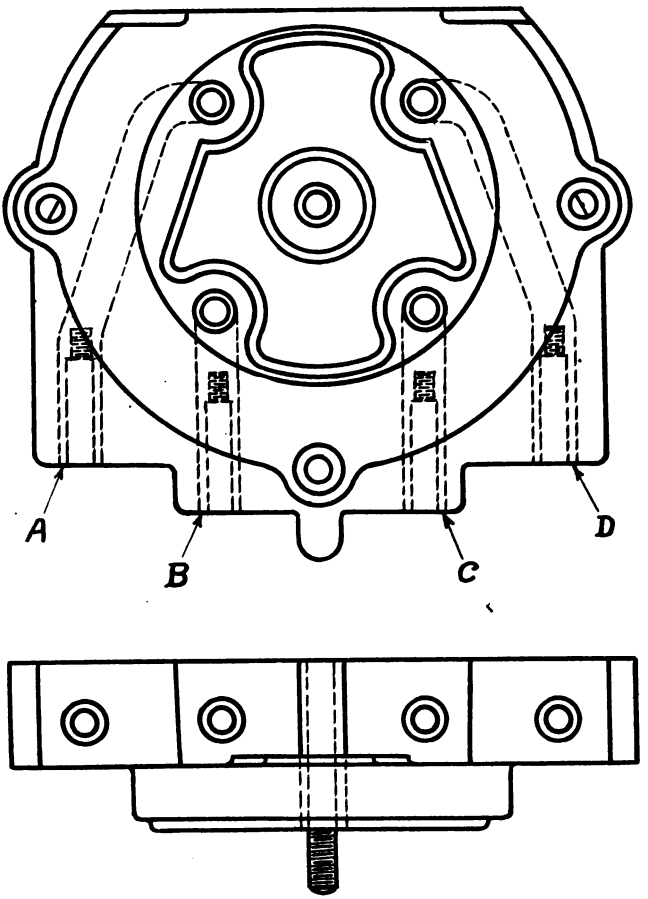


FIG. 18

tioned for parts of this nature. This trouble was caused by either the materials not being heatproof enough or else by being affected by the oil and gasoline vapors.

The ceramic materials of Class "D" could not be used, as the molding could not have been done accurately enough or no metal parts could have been molded in, and also these materials could not stand the vibration to which they would necessarily be subjected in an automobile.

The inorganic cold molded materials of Class "C" could not have been satisfactorily employed for the molding of these parts for two reasons. They could not be molded accurately enough, and furthermore, as such parts should be safe to withstand at least 3,000 volts continuously, the insulating properties of this product would not be sufficient.

The materials of Class "B" could not be molded accurately enough, and they are primarily adaptable for use under working conditions below 1,000 volts.

The products best suited for such parts and which fulfill all the requirements are the materials of Class "G." These materials are already almost entirely employed for such purposes.

In the molding of such shapes of materials of Classes "B" and "C," the four inserts A, B, C and D would present some difficulties owing to the high pressure required in the pressing. These inserts, as shown in Figure 18, can only be supported at their extremities, and there would be great danger of their distorting between the supporting points.

Therefore, the principal feature to bear in mind is the position and shape of the inserts, and that they be designed and located so that they may be easily and firmly held in position and sufficiently supported so that they will not bend or distort during the molding process.

SELECTION OF MATERIALS IN RELATION TO DESIGN AND USES OF INSULATING PARTS

The molding, physical, mechanical, electrical, and other properties of the different classes of materials, as they affect their relative adaptability to the production of various molded articles, has been treated in previous chapters. This question is, however, of such vital importance to the designer and electrical engineer that the author has thought it advisable to offer some further suggestions, aided by illustrations, which, it is hoped, will prove helpful to those having to select the material best suited to their purpose from among the classes treated in this work. Since entirely legitimate differences of opinion must exist as to what may be required of an insulating material for a given purpose, these suggestions are evidently not offered as final or as applying to every circumstance that may arise.

The author's long and intimate experience in manufacturing materials of all of the classes treated, as well as his personal and business relations with the foremost electrical designers and engineers, permitting him, as they do, to base these suggestions on the experience of the past ten years both in the laboratory and in actual service, leads him to believe that they will be of some assistance to those seeking information. No reference to Class "H," the fibre products, will be made, for, as previously stated, materials of this class are principally

used in the form of sheets, rods, and tubes only, and machined into the desired shapes. Class "I," mica molded articles is also excluded, they being restricted to the usual known micanite segments, rings, tubes, sheets and such forms. When referring, therefore, to parts which may be molded of materials of all classes, it must be understood that Classes "H" and "I" are not included.

PLATE I

PLATE II

Plates Nos. I. and II.

Parts of familiar design are here shown, which may be molded from materials of all of the six classes, though for practical reasons, the ceramic products of Class "D" are almost exclusively used at the present time in the production of these and similar parts. This is partly due to the excellent dielectric and physical characteristics of porcelain, but principally to its low cost. As a result, the combined production of such parts from materials of the other classes is far below that of Class "D," the ceramic products.

Ten years ago, porcelain alone was available for such parts, but since that time other classes of molded materials, such as those of Classes "B" and "C" have grown in favor, so that at the present time the designer of electrical appliances is no longer limited to porcelain, but has at his disposal both the inorganic and organic cold molded materials of Classes "B" and "C," giving him a wider range as to appearance and physical qualities, where very low cost is not an absolute essential.

The hot molded materials of Class "A" are also available, and sometimes used where resistance to heat is not required. Also the synthetic resinous materials of Class "G," but only when cost need not be considered.

PLATE III

Plate No. III.

VARIOUS TYPES OF SWITCH HANDLES

Appearance and finish are the essentials in such parts. They are also generally molded with metal studs or blades in place. The production of such parts is practically limited to the hot molded materials of Class "A," which, high heat-resistance not being of importance, best fill the requirements as to finished appearance and low cost. The synthetic resinous materials of Class "G" are also entirely suitable, but are debarred owing to their high cost.

The cold molded materials of Classes "B" and "C" may be molded into such shapes, but owing to the uneven surfaces, they cannot be polished and finished as well as materials of Class "A."

The ceramic products of Class "D" were at one time employed to a limited extent, but have now been almost entirely superseded.

Materials of Class "E" (rubber compounds) are no longer used for such purposes.

PLATE IV

Plate No. IV.

A FURTHER VARIETY OF SMALL SWITCH HANDLES AND KNOBS OFFERING MORE LATITUDE IN THE CHOICE OF MATERIALS THAN THOSE SHOWN IN PLATE NO. III

The first points for consideration in selecting a material for these parts being cost and appearance, the products of Class "A" are most adaptable, though these forms, being more regular than those shown in Plate No. III, and being readily and rapidly polished, may also be produced of the products of Class "B," with very little increase in the cost. In cases where heat-resistance is required, the materials of Class "B" are, therefore, used, being very little inferior to those of Class "A" in appearance, and possessing all of the other desirable properties.

The ceramic products, Class "D" are not used for such parts, and materials of Class "G," synthetic resinous products, while entirely suitable, can only be used when cost need not be considered.

The inorganic materials of Class "C" are not used, owing to their inferior finish, while the rubber compounds of Class "E," at one time employed, are now rarely, if ever, seen.

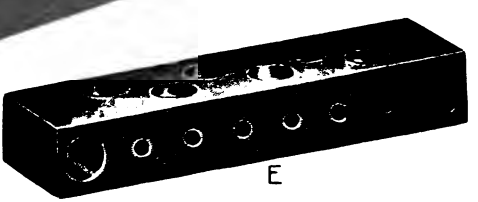
A

B

C

F

D



E

PLATE V

Plate No. V.

MOLDED ARTICLES MOSTLY FOUND IN TELEPHONE WORK

Resistance to heat being unimportant, materials of Classes "A" and "E" are most suitable, particularly for parts illustrated by Figures A and B, owing to the high and permanent finish required, and by Figure C, owing to the multiplicity of small and delicate metal parts which are molded into the material.

While materials of Class "G" are in every way suitable, their comparatively high cost has, up to now, precluded their general use.

The materials of Classes "B" and "C" are entirely unsuitable for the style of pieces shown by Figures A and B, though in some cases they might prove satisfactory for pieces similar to Figure C.

Materials of Classes "B" and "C" are suitable for molding parts shown in Figures D, E and F, particularly the latter in the larger sizes, or where used in installations in which they may be exposed to heat.

PLATE VI

Plate No. VI.

OVERHEAD LINE INSULATORS

Formerly, these parts were made of the rubber compounds of Class "E," but today they are almost exclusively made of the organic hot molded materials of Class "A."

Materials of Classes "B" and "C," while desirable owing to their heat-resisting qualities in case of line short circuits, have not been successfully used, due to difficulties in molding the forms and metal inserts required, as has been more fully explained in considering similar parts in a previous chapter.

Materials of Class "G" would be ideal for this purpose were it not for their high cost. Whether or not this may be justified by their superior properties has not yet been definitely determined, as the synthetic resinous products are of too recent origin and sufficient comparative data as to behavior under service conditions is not available.

PLATE VII

Plate No. VII.

MAGNETO DISTRIBUTOR, COLLECTOR, AND SIMILAR PARTS

Hot molded materials are only suitable for molding such parts, as has been more fully explained in considering a similar piece in the chapter on molds and dies.

In the past, materials of Classes "A" and "E" were used, but recently they have been superseded by the synthetic resinous materials of Class "G" which are pre-eminently adopted for this purpose to the exclusion of materials of any of the other classes. Owing to their heat-resisting qualities and lower cost, repeated efforts have been made to render the materials of Classes "B" and "C" adaptable to this purpose, but as yet without any marked success.

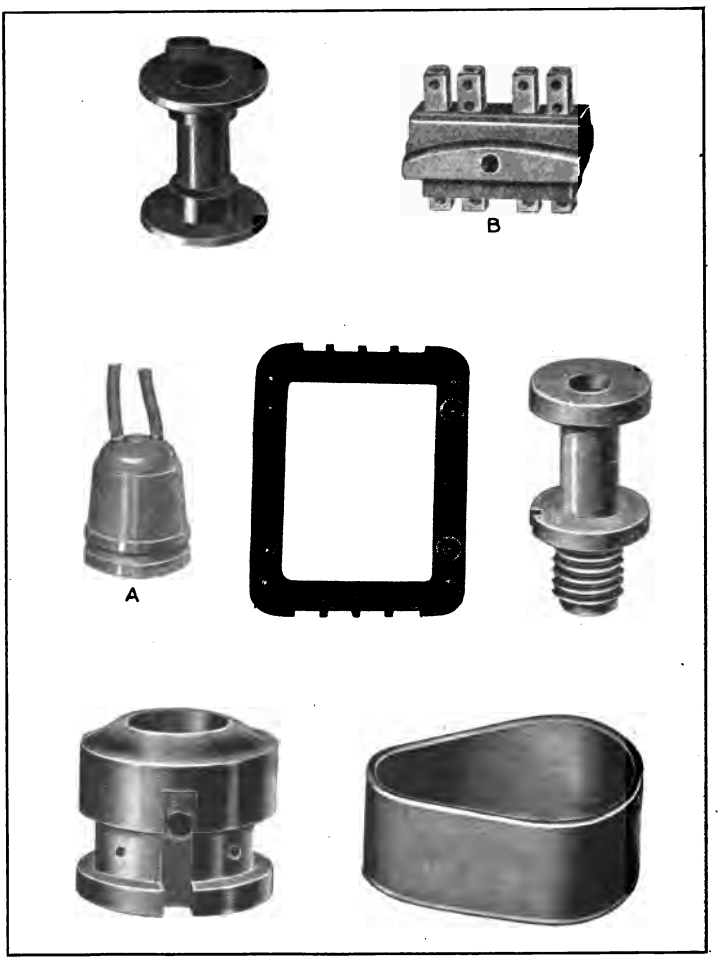


PLATE VIII

Plate No. VIII.

A FURTHER SERIES OF PARTS SIMILAR TO THOSE OF PLATE NO. VII

These parts are best made of the hot molded materials of Classes "A" and "G." Formerly, only the materials of Class "A" were available, but to-day the synthetic resinous materials of Class "G" receive favorable consideration where cost is of secondary importance.

Cold molded materials of Classes "B" and "C" are not recommended, and the ceramics of Class "D" are entirely unsuitable. Pieces of this style, shown by Figures A and B particularly, can only be successfully produced in materials of Classes "A" and "G."

In Figure A, this is due to the insulated wires which could not be properly molded into place under the cold molding processes, and would further be rendered useless through the destruction of their insulating cover by the high temperatures to which these products are usually subjected after the pressing operation.

In Figure B, this is due to the metal parts which could not be successfully molded in under the cold molding processes.

In fact, the accuracy of dimensions and complication of shapes required in parts shown in this cut can only be produced with facility, in the materials of Classes "A" and "G," and therefore, materials of Classes "B" or "C" should only be considered in special cases where the peculiar characteristics of these materials may be necessary.

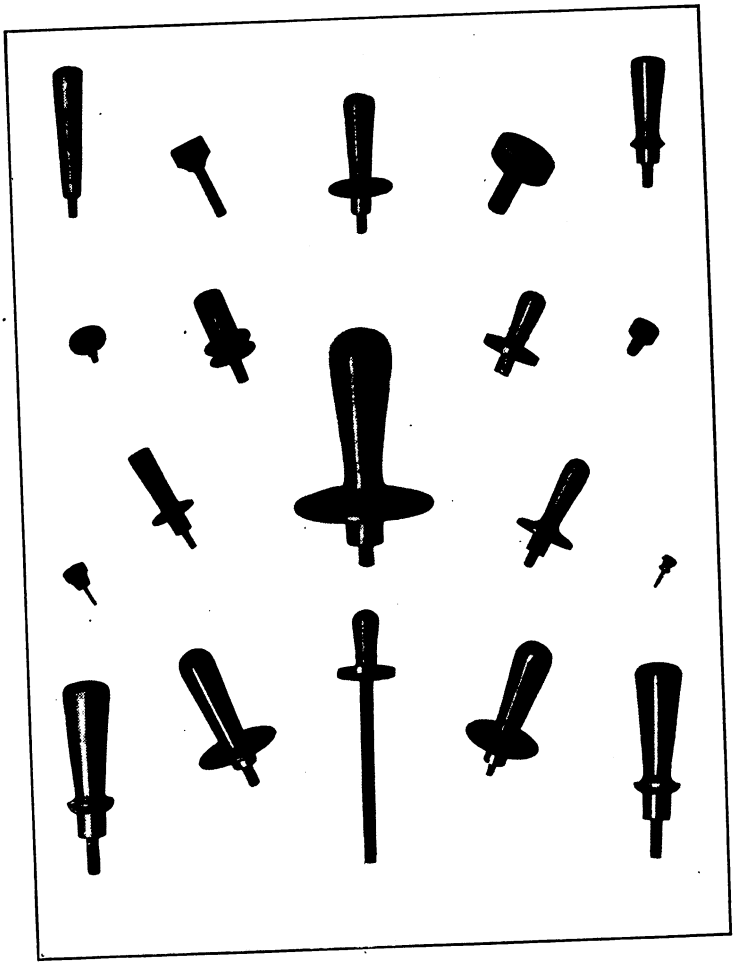


PLATE IX

Plate No. IX.

A SERIES OF INSULATING HANDLES

In the United States, these parts have up to the present time been almost entirely made of wood, though to a lesser extent, materials of Class "A' have been used, and very recently materials of Classes "B" and "C" have been considered.

It would seem strange that, while in Europe, more especially in Germany, the strict regulations of Fire Underwriters have debarred wood as unsafe, no strong movement has taken place in the United States in favor of molded materials, though this is probably due to the cheapness of wood.

It is, however, the author's belief that, as fibre and wood have been superseded by molded materials for other purposes, they will, in the near future, be displaced by molded materials.

The higher cost will be more than compensated by superior dielectrical and physical qualities. Such switch handles are used under varying conditions of heat and moisture, rendering them liable, when made of wood, to shrink or expand, with the result that metal parts will split the handles or become loose, and in consequence be a source of actual danger.

Owing to the great number of suitable molded materials available, no difficulty should be experienced in selecting a satisfactory product. For this purpose the synthetic resinous materials of Class "G" are the best where cost need not be considered, but are closely followed by the hot molded materials of Class "A" and, more recently, by the cold molded materials of Class "B."

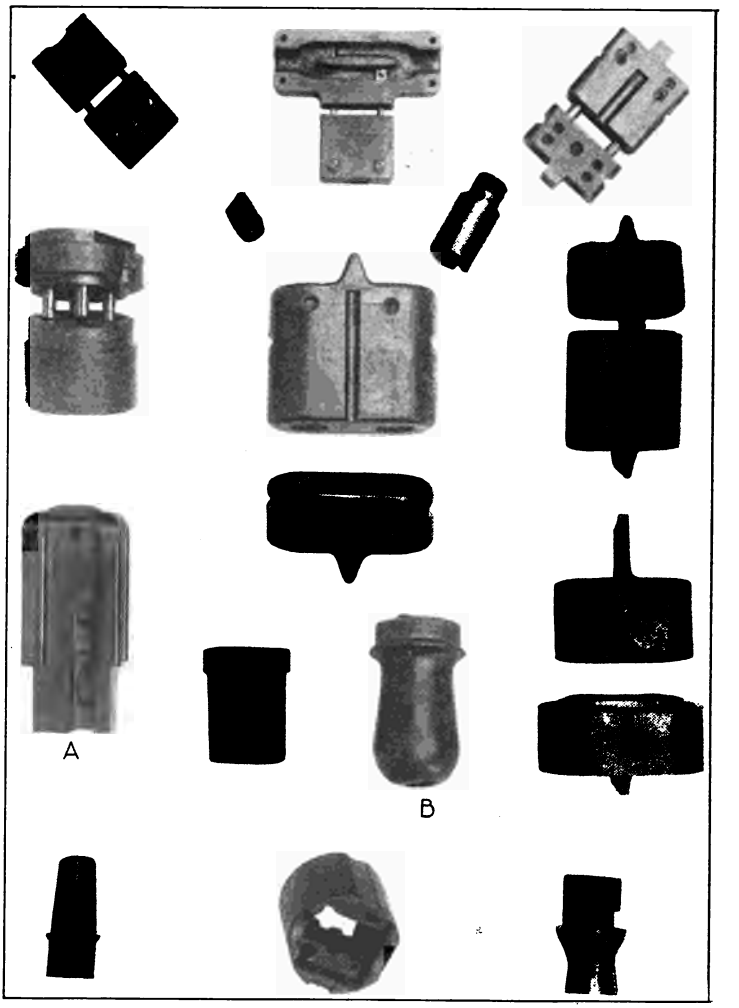


PLATE X

Plate No. X.

A SERIES OF CHARGING OR CONTACT PLUGS AND SIMILAR PARTS

These pieces being subjected to very rough treatment in service, require a material which is tough and will not chip or crack under hard blows.

Owing to the high amperages generally carried by these parts, heat-resistance is an essential to prevent any danger of fire or deterioration of the insulation by charring, when contacts are made and broken. Until recently materials of Class "A" were used, but they have now been discarded as unsafe owing to their lack of resistance to heat. Vulcanized fibre is at present very much in favor owing to its toughness and non-inflammability, but still leaves much to be desired as it will in time char, and is very sensitive to conditions of moisture and dryness in the atmosphere which cause it to distort with a consequent displacement of metal contact parts. In view of the above, and the further fact that fibre must be machined to obtain the desired shapes, it would seem that the molded products will in the very near future be called on to advantage and fibre entirely superseded.

Materials of Classes "B," "C" and "G" will be found well adapted to this purpose, owing to their high heat-resistance and indifference to moisture, "B" and "C" being used where cost is a consideration, and "G" for parts of intricate shapes where cost may be disregarded.

The ceramics, Class "D," are entirely unsuitable, and the rubber compounds of Class "E" are seldom used.

The parts shown in the plate with the exception of Figure A, made of synthetic resinous material, Class "G," and Figure B, made of hot molded organic material of Class "A," are all made of the cold molded materials of Classes "B" and "C" and have been in successful commercial use for a number of years.

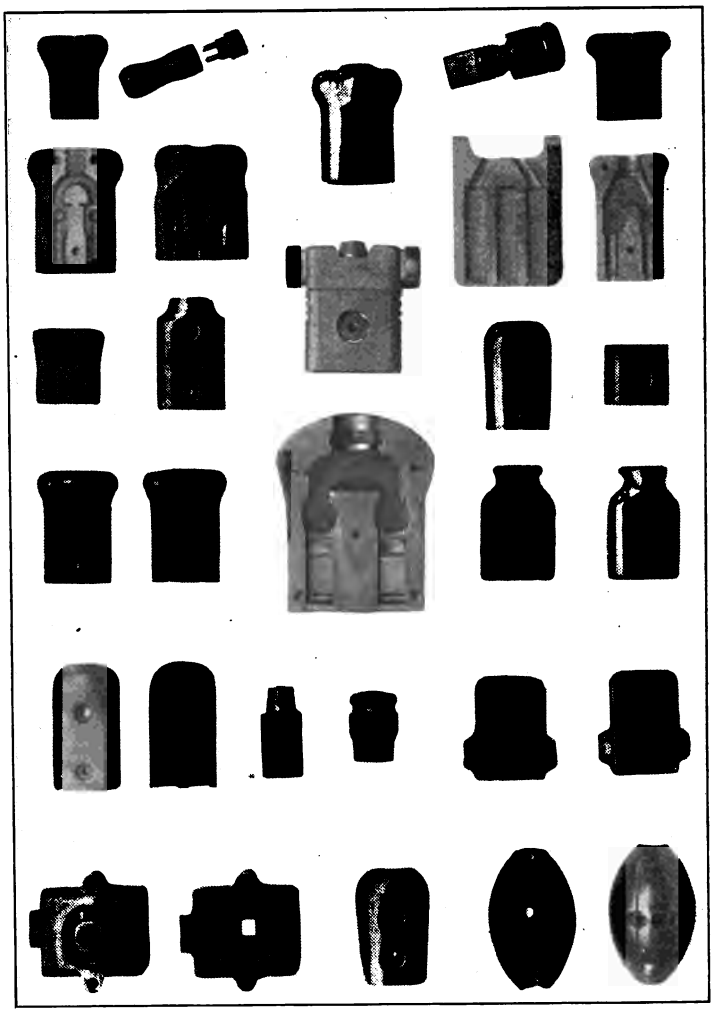


PLATE XI

Plate No. XI.

VARIOUS CONNECTOR OR PLUG PARTS PRINCIPALLY USED WITH ELECTRIC FLAT IRONS AND OTHER ELECTRICAL HEATING APPLIANCES

The primary requisite for such parts is resistance to heat, as they must necessarily come in direct contact with the hot metal parts of the appliances which they connect to the source of current. Under normal conditions, 300° C. without softening or other deterioration is the usual temperature limitation.

Furthermore, these parts being furnished as part of a household article, must be well finished in appearance.

Before the introduction of the cold molded organic materials of Class "B," the only available products were porcelain, and some molded material depending on a large proportion of asbestos for the necessary heat-resistance.

The former, owing to its brittleness and consequent liability to chipping has been almost totally abandoned, except in a few cases, where it is protected by an outer metal casing. The latter, owing to its heavy asbestos content, was rough and unsightly, and, therefore, discarded.

At the present time, materials of Class "B" above referred to, are almost exclusively used, though in some exceptional cases of special design, materials of Class "C" are preferred, owing to their higher heat-resistance. Materials of Classes "E" and "G" are not used, partly owing to their prohibitive cost, but principally because they are not as heat-resisting as Classes "B" and "C."

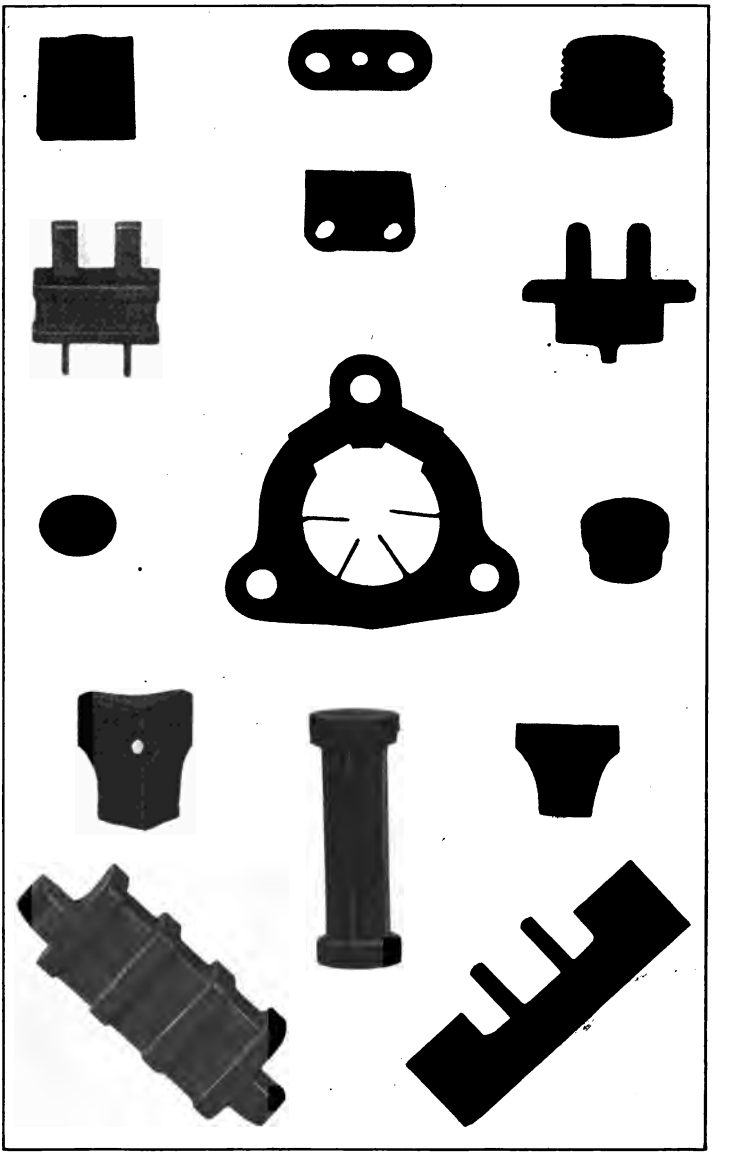


PLATE XII

Plate No. XII.

TERMINAL BUSHINGS, CONTACT PARTS, ETC., REQUIRING HIGH HEAT-RESISTING QUALITIES

The majority of these pieces are used to insulate contacts of electric flat irons or other heating appliances, and, being permanently located inside of the latter or even attached directly to the heating element, must necessarily stand continuous high temperatures, the minimum requirement being 800° C.

While the ceramic materials of Class "D" would stand the heat required, they have been little used for this purpose, due to the impossibility of molding metal contacts in place, and the attainment of the required degree of accuracy to insure a proper fit between the male and female contacts.

Materials of Class "A" are, of course, entirely unsuitable, while those of Classes "E" and "G," and even Class "B," are not sufficiently heat-resisting.

The only remaining available materials are those of Class "C" which, when made with a proper regard for the heat conditions to be met, are entirely suitable and almost exclusively adopted for this purpose.

PLATE XIII

Plate No. XIII.

ARC DEFLECTORS, SEPARATORS AND SIMILAR PIECES USED IN ELECTRIC CONTROLLERS AND AUTOMATIC APPARATUS SUBJECTED TO CONTINUOUS ARCING

By referring to the previous treatment of this subject, it will be readily understood that no material containing organic substances in any form could be considered for this purpose.

The only suitable materials, therefore, are the ceramics of Class "D," and the cold molded inorganic products of class "C." The latter predominate, however, owing to their mechanical advantages, porcelain being used only in a few instances.

PLATE XIV

Plate No. XIV.

RAILROAD THIRD RAIL AND SIGNAL PARTS

Figures A, B, C and D illustrate a series of third rail insulators for service on the regular 660 volt circuit.

Figures C and D are satisfactorily produced in the materials of Classes "A," "B," "C," "D" and "G," though the ceramics predominate at the present time owing to their low cost. Figures A and D can only be produced in the materials of Classes "A," "B," "C" and "G," owing to the heavy metal parts which are molded in place.

As regards suitability, it is generally accepted that the ceramics are superior regarding their dielectric and physical attributes, while the products of Classes "A," "B," "C" and "G" are superior mechanically.

The essentials are dielectric and mechanical stability under long term of service in all weather conditions; these have been successfully met by materials of Classes "B," "C" and "G" under observation for four years in actual use.

The ceramics, though satisfactory in every other respect and lower in cost, are liable to excessive breakage.

The other parts shown in this cut, used in electric signaling apparatus, are now made in materials of Classes "G" or "C." The former are preferred when absolute accuracy is required, but where variations of from 5 to 10 thousandths per inch may be allowed, the materials of Classes "B" and "C" are very suitable.

Materials of Classes "A" and "E" are rarely used for such purposes.

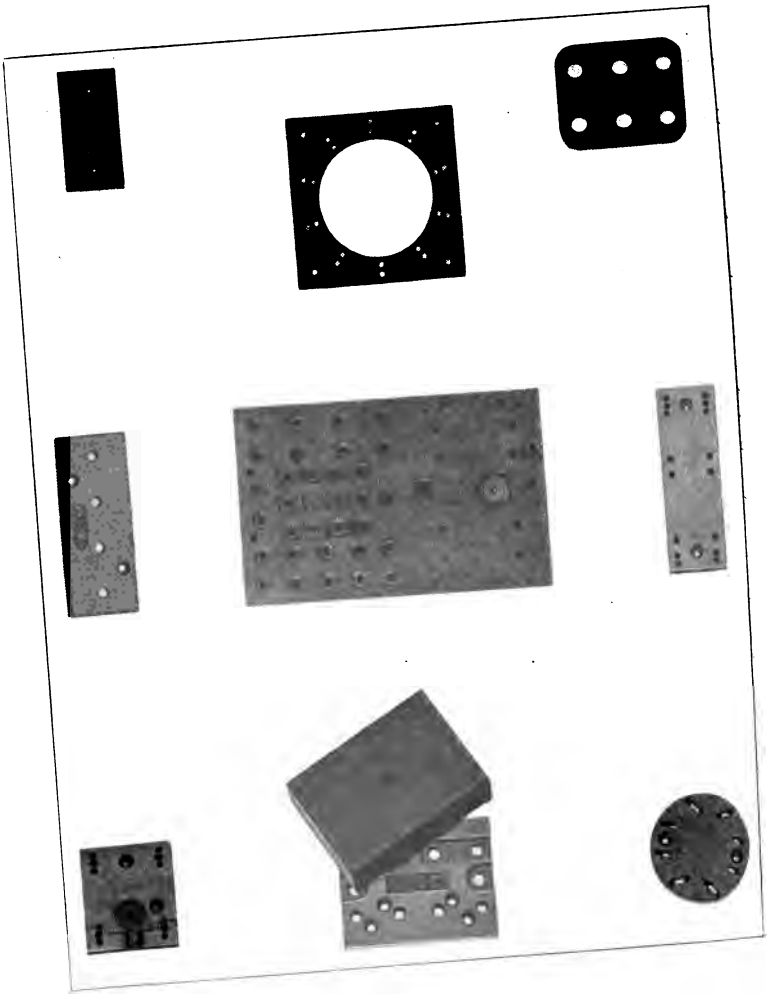


PLATE XV

Plate No. XV.

MOLDED BASES AND COVERS

Hitherto, such parts have been cut from slate and fibre, but more recently there has been a very distinct tendency in favor of molded materials with the preference given to products of Classes "C" or "G," and to a lesser degree, Classes "A" and "B." Accurate molding and low cost, as well as dielectric and mechanical suitability have placed materials of Class "C" in the lead, while Class "G" has served for special purposes.

The ceramics of Class "D" are not as suitable, owing to the difficulty of obtaining perfectly flat surfaces.

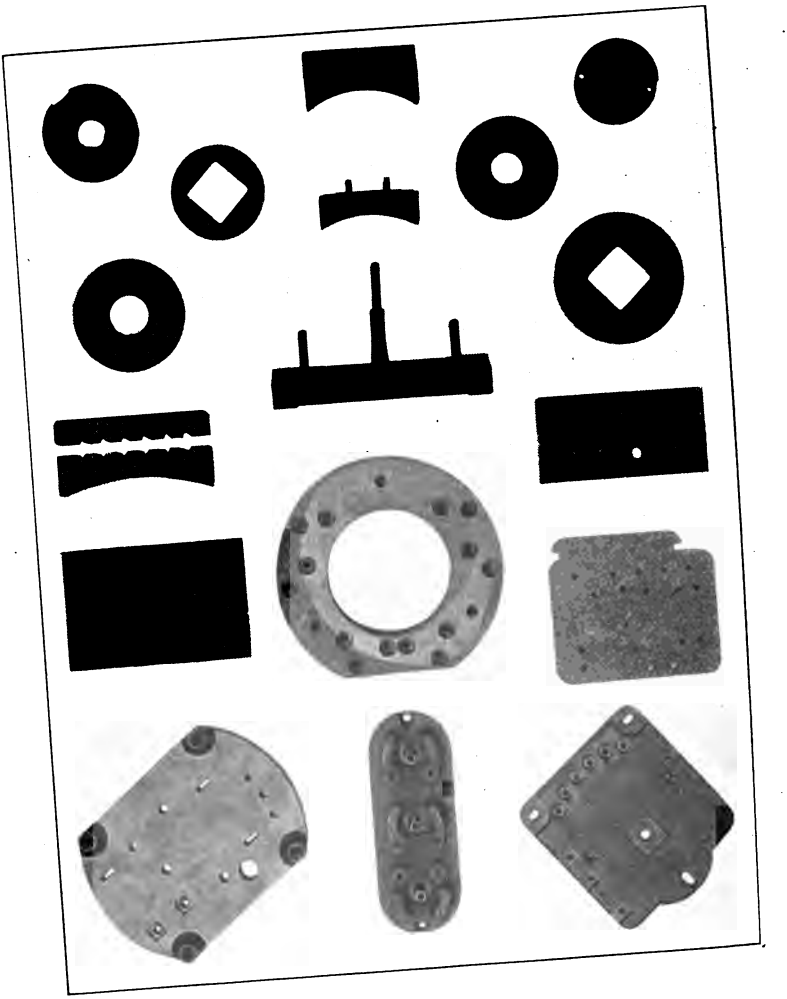


PLATE XVI

Plate No. XVI.

SPECIAL MOLDED PARTS USED IN CONNECTION WITH ELECTRIC MOTORS, FANS AND APPLIANCES

Materials of Classes "B," "C" and "G" are the most suitable for such parts, as the apparatus in which they are used, is, at times, liable to overheating and it is, therefore, important that the insulation used should stand temperatures of not less than 100° C., without softening.

Materials of Class "D" are used, owing to their low cost, but are gradually being superseded, owing to the greater accuracy and better mechanical features obtained with materials of the other classes.

Materials of Class "G" can be molded in such shapes with absolute accuracy, while materials of Classes "B" and "C" require a variation allowance of a few thousandths per inch.

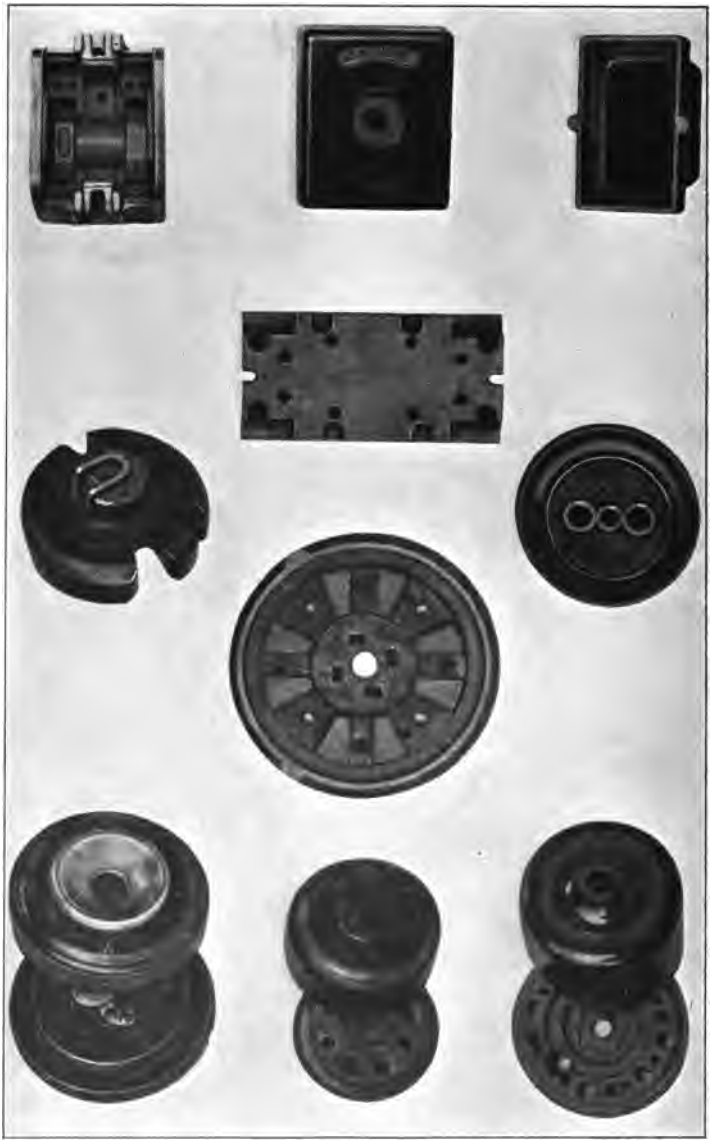


PLATE XVII

Plate No. XVII.

SWITCH BASES, COVERS AND RECEPTACLES

Ten years ago porcelain was the only material used for these bases and receptacles, while the covers were made of Class "A," or more often of stamped metal lined with insulating paper or fibre.

Since that time, however, the introduction of materials of Class "B" has opened a wider choice to designers, and many are availing themselves of the advantages to be obtained from the use of these products.

Materials of Class "B" have, in fact, been found satisfactory for receptacles, bases, and covers, permitting of the production of complete assembled parts in the same material.

In European countries, there has been a very marked movement in favor of materials of Class "B" for the production of these parts, while in the United States the tendency, though more gradual, would seem to indicate their favorable consideration among many of the leading manufacturers of electrical appliances.

The designer may, therefore, safely follow his own judgment, selecting materials of Class "D" if he desires to be conservative and follow in the lines of established practice, or by selecting materials of Class "B" if he desires to avail himself of the greater accuracy and consequent reduced assembly difficulties offered.

PLATE XVIII

Plate No. XVIII.

ATTACHMENT PLUGS AND PARTS

Until very recently these parts have been made of porcelain, or where a tougher material was required, of Class "A" products. At present, however, materials of Class "B" offering, as they do, the heat-resisting qualities of porcelain with the toughness of Class "A" products, are also very extensively used.

To a limited extent, owing to their comparatively high cost, materials of Classes "G" and "E" are also used.

In fact, the choice between Class "D" and Class "B" materials would seem to be a matter of individual preference, both being considered satisfactory, with a growing tendency in favor of the latter.

LABORATORY TESTS

In describing the various classes of molded insulating materials and their properties, relative values have been considered only in the abstract, while in the chapter covering the selection of materials and illustrating typical molded parts, a more definite attempt has been made to distinguish between the classes, and to establish their individual merits for specific purposes on the basis of results obtained and present day usage in the electrical industry.

As far as possible, reference to definite laboratory tests has been avoided, as liable to be misleading, partly due to a want of standardized methods in testing molded insulating materials, but principally due to variations in the quality of raw materials and methods of manufacture. Practically all published information available, up to the present, has been obtained from manufacturers of the various molded insulating products, or at best, from tests made on samples furnished for this specific purpose. Comparisons based on such data are seldom conclusive and cannot, therefore, be considered a safe guide in determining the most suitable insulating product to be specified for any particular purpose. In fact, it is generally accepted, among electrical engineers, that they must depend on their own tests, though they are most often governed by the more practical con-

sideration of length of service and reliability established by common experience.

Owing to their scientific and general interest, however, the author has felt that laboratory tests should be accorded a place in this work.

In order to render such tests as nearly as possible comparative, commercial samples of the more generally manufactured insulating products have been procured rather than special samples prepared with a knowledge of the purpose for which they were required.

The results given do not, therefore, cover all of the products of the classes of materials tested, as these would show wide differences due to variations in methods of preparation, quality of binders and fillers used, and conditions of manufacture. It follows in some instances that, as has already been stated, the reverse of conclusions based on such tests would hold where products, seemingly inferior under the laboratory test, would prove superior for practical purposes of service.

In the tests which follow, reference has, in some cases, been made to two or three products of the same class indicated by the letters a, b, etc. This has been done to demonstrate the wide range of results that may be obtained from different commercial products manufactured on the same general principle and in the same class of material.

Materials of Classes "D," "E," "F," "H" and "I" being more generally known and understood, it has not been thought necessary to give them a place in these tests which are confined to the more recently introduced materials of Classes "A," "B," "C" and "G."

All of the figures given have been prepared under the personal supervision of Mr. F. M. Farmer, of the

Electrical Testing Laboratories of New York.

In some cases, the form of test has been suggested by the author to, as nearly as possible, approach practical conditions as met in his own experience.

DIELECTRIC STRENGTH TESTS

These tests were made with samples of the following shapes and obtained as follows:

Class "A." Plates 2½"x1⅞"x½" cut from molded plates 6"x4"x½".

Class "A" (a). Molded bushing, irregular shape, 3"x 2⅜" over all.

Class "B." Cover, over all, dimension 2⅜"x2⅜"x 1⅜" high, width, ½" wall.

Class "B" (a). Caps for hexagonal nuts or bolts, maximum width of head, 1", thickness of wall, ½".

Class "C." Plates 3¼"x2½"x5/16" thick, cut from one plate 5"x7"x5/16".

Class "C" (a). Plates 3"x3"x⅜" cut from one plate 7"x7"x⅜".

Class "G." Plates 4"x2⅝"x⅜" cut from one plate 8"x6"x½".

Class "G" (a). Plates 4"x2⅝"x½" cut from one sheet 8"x8"x½".

Class "G" (b). Molded bushing 1⅝"x1¾" over all.

The dielectric strength tests were made with the sample placed between blunt needle points; voltage was applied to the needle points at a low value, and gradually

increased, until puncture occurred. The high tension voltage was measured by means of a voltmeter connected across the low tension winding of the transformer, the ratio being known. The current was obtained from a 60 cycle course, the wave form of which is practically a sine curve.

SAMPLE TESTED AS RECEIVED

		Volts Per Mil.
Class "A"	Specimen No. 1	152
	Specimen No. 2	178
	Specimen No. 3	143
Class "A" (a)	Specimen No. 1	361
	Specimen No. 2	350
	Specimen No. 3	353
Class "B"	Specimen No. 1	91.8
	Specimen No. 2	83.5
	Specimen No. 3	88.0
Class "B" (a)	Specimen No. 1	167.0
	Specimen No. 2	148.7
	Specimen No. 3	159.3
Class "C"	Specimen No. 1	69.5
	Specimen No. 2	72.2
	Specimen No. 3	70.8
Class "G"	Specimen No. 1	46.2
	Specimen No. 2	41.7
	Specimen No. 3	45.0
Class "G" (a)	Specimen No. 1	221
	Specimen No. 2	213
	Specimen No. 3	218
Class "G" (b)	Specimen No. 1	326
	Specimen No. 2	315
	Specimen No. 3	333

SAMPLES TESTED AFTER IMMERSION IN WATER FOR 72 HOURS

		Volts Per Mil.
Class "A"	Specimen No. 1	114
	Specimen No. 2	110
	Specimen No. 3	103
Class "A" (a)	Specimen No. 1	287
	Specimen No. 2	293
	Specimen No. 3	301
Class "B"	Specimen No. 1	53
	Specimen No. 2	58
	Specimen No. 3	55
Class "B" (a)	Specimen No. 1	121
	Specimen No. 2	118
	Specimen No. 3	107
Class "C"	Specimen No. 1	42
	Specimen No. 2	40
	Specimen No. 3	45
Class "G"	Specimen No. 1	40
	Specimen No. 2	36
	Specimen No. 3	38
Class "G" (b)	Specimen No. 1	235
	Specimen No. 2	228
	Specimen No. 3	241

SAMPLES TESTED AFTER IMMERSION IN TRANSFORMER OIL AT 75° C. FOR 72 HOURS

		Volts Per Mil.
*Class "A"	Specimen No. 1	152
	Specimen No. 2	170
	Specimen No. 3	164
Class "B"	Specimen No. 1	193
	Specimen No. 2	169
	Specimen No. 3	188
Class "C"	Specimen No. 1	145
	Specimen No. 2	149
	Specimen No. 3	147
Class "G"	Specimen No. 1	30.3
	Specimen No. 2	29.8
	Specimen No. 3	31.0
Class "G" (a)	Specimen No. 1	186
	Specimen No. 2	184
	Specimen No. 3	180

*NOTE—Samples blistered and were slightly deformed after test.

SAMPLES TESTED AFTER SUBJECTION TO A TEMPERATURE OF 100° C. FOR 12 HOURS

		Volts Per Mil.
*Class "A"	Specimen No. 1	87.7
	Specimen No. 2	91.1
	Specimen No. 3	86.0
Class "B"	Specimen No. 1	90.0
	Specimen No. 2	84.0
	Specimen No. 3	91.0
Class "C"	Specimen No. 1	70.0
	Specimen No. 2	73.0
	Specimen No. 3	68.0
Class "G"	Specimen No. 1	65.7
	Specimen No. 2	67.0
	Specimen No. 3	63.0
Class "G" (a)	Specimen No. 1	163.5
	Specimen No. 2	159.6
	Specimen No. 3	166.0

*NOTE—Samples blistered and were slightly deformed after test.

SAMPLES TESTED AFTER SUBJECTION TO A TEMPERATURE OF 200° C. FOR 12 HOURS

		Volts Per Mil.
*Class "A"	Specimen No. 1	67.0
	Specimen No. 2	60.0
	Specimen No. 3	62.6
Class "B"	Specimen No. 1	98.0
	Specimen No. 2	101.0
	Specimen No. 3	96.0
Class "C"	Specimen No. 1	74.0
	Specimen No. 2	79.0
	Specimen No. 3	76.0
Class "G"	Specimen No. 1	102.5
	Specimen No. 2	109.0
	Specimen No. 3	101.0
**Class "G" (a)	Specimen No. 1	119.0
	Specimen No. 2	116.0
	Specimen No. 3	124.0

*NOTE—Samples were swollen up after test and entirely deformed.

**NOTE—Samples were blistered and slightly deformed after test.

SAMPLES TESTED AFTER SUBJECTION TO A TEMPERATURE OF 300° C. FOR 12 HOURS

		Volts per Mil.
*Class "A"	Specimen No. 1	...
	Specimen No. 2	...
	Specimen No. 3	...
Class "B"	Specimen No. 1	96
	Specimen No. 2	105
	Specimen No. 3	102
Class "C"	Specimen No. 1	94
	Specimen No. 2	90
	Specimen No. 3	96
*Class "G"	Specimen No. 1	...
	Specimen No. 2	...
	Specimen No. 3	...
*Class "G" (a)	Specimen No. 1	...
	Specimen No. 2	...
	Specimen No. 3	...

*NOTE—Unable to test because of change caused by heat.

SAMPLES TESTED AFTER SUBJECTION TO A TEMPERATURE OF 300° C., COOLING AND THEN SUBJECTING TO IMMERSION IN WATER FOR 24 HOURS

		Volts per Mil.
*Class "A"	Specimen No. 1	...
	Specimen No. 2	...
	Specimen No. 3	...
Class "B"	Specimen No. 1	80
	Specimen No. 2	78
	Specimen No. 3	83
Class "C"	Specimen No. 1	55
	Specimen No. 2	57
	Specimen No. 3	54
*Class "G"	Specimen No. 1	...
	Specimen No. 2	...
	Specimen No. 3	...
*Class "G" (a)	Specimen No. 1	...
	Specimen No. 2	...
	Specimen No. 3	...

*NOTE—Not tested because of change caused by heat.

INSULATION RESISTANCE TESTS

The samples submitted for this test were the same as those used for the puncturing tests. They were first used for measurements of the resistance, and afterwards for the puncture tests.

The insulation resistance was measured by the usual high sensibility series galvanometer method, the time of electrification being one minute. Voltage of 150 and 700 volts were employed, depending upon the value of insulation resistance to be measured. The electrodes employed were containers. A guard ring was employed so that the question of surface leakage was thereby eliminated.

When the immersed samples were withdrawn from the water, the excess surface moisture was removed with blotting paper. Since the samples were very small and the guard ring near the edge, it is probable that the leakage current was relatively large and the result must be considered of questionable value.

SAMPLES TESTED AS RECEIVED

		Insulation resistance megohms per inch, cube
Class "A"	Specimen No. 1	235,710
	Specimen No. 2	60,700
	Specimen No. 3	174,200
Class "A" (a)	Specimen No. 1	Greater than 1,000,000
	Specimen No. 2	" " 1,000,000
Class "B"	Specimen No. 1	21,300
	Specimen No. 2	18,070
	Specimen No. 3	12,300
Class "B" (a)	Specimen No. 1	51,200
	Specimen No. 2	40,700
Class "C"	Specimen No. 1	290,000
	Specimen No. 2	115,000
	Specimen No. 3	240,000
Class "C" (a)	Specimen No. 1	24,900
	Specimen No. 2	28,100
Class "G"	Specimen No. 1	65
	Specimen No. 2	93
	Specimen No. 3	76

SAMPLES TESTED AFTER IMMERSION IN WATER FOR 72 HOURS

		Insulation resistance megohms per inch, cube
Class "A"	Specimen No. 1	513
	Specimen No. 2	890
	Specimen No. 3	1070
Class "A" (a)	Specimen No. 1	800,000
	Specimen No. 2	600,000
Class "B"	Specimen No. 1	470
	Specimen No. 2	380
	Specimen No. 3	710
Class "B" (a)	Specimen No. 1	14,300
	Specimen No. 2	17,210
Class "C"	Specimen No. 1	900
	Specimen No. 2	1,320
	Specimen No. 3	1,150
Class "C" (a)	Specimen No. 1	21,110
	Specimen No. 2	19,000
Class "G"	Specimen No. 1	51.0
	Specimen No. 2	40.0
	Specimen No. 3	42.0
Class "G" (a)	Specimen No. 1	7,590
	Specimen No. 2	11,400
	Specimen No. 3	8,100
Class "G" (b)	Specimen No. 1	6,250
	Specimen No. 2	5,600

SAMPLES TESTED AFTER SUBJECTION TO A TEMPERATURE OF 100° C. FOR 12 HOURS

		Insulation resistance megohms per inch, cube
*Class "A"	Specimen No. 1	Greater than 1,000,000
	Specimen No. 2	" " 1,000,000
	Specimen No. 3	" " 1,000,000
Class "B"	Specimen No. 1	25,800
	Specimen No. 2	36,100
	Specimen No. 3	30,400
Class "C"	Specimen No. 1	Greater than 1,000,000
	Specimen No. 2	" " 1,000,000
	Specimen No. 3	" " 1,000,000
Class "G"	Specimen No. 1	1,790
	Specimen No. 2	2,310
	Specimen No. 3	3,840
Class "G" (a)	Specimen No. 1	250,000
	Specimen No. 2	340,000
	Specimen No. 3	376,000

*NOTE—Samples blistered and warped slightly.

SAMPLES TESTED AFTER SUBJECTION TO A TEMPERATURE OF 200° C. FOR 12 HOURS

			Insulation resistance megohms per inch, cube
*Class "A"	Specimen No. 1	Greater than	1,000,000
	Specimen No. 2	" "	1,000,000
	Specimen No. 3	" "	1,000,000
Class "B"	Specimen No. 1		350,000
	Specimen No. 2		405,000
	Specimen No. 3		341,000
Class "C"	Specimen No. 1	Greater than	1,000,000
	Specimen No. 2	" "	1,000,000
	Specimen No. 3	" "	1,000,000
**Class "G"	Specimen No. 1		850,000
	Specimen No. 2		970,000
	Specimen No. 3		680,000
**Class "G" (a)	Specimen No. 1	Greater than	1,000,000
	Specimen No. 2	" "	1,000,000
	Specimen No. 3	" "	1,000,000

*NOTE—Samples blistered and swelled badly.

**NOTE—Samples blistered and swelled slightly.

TENSILE STRENGTH TESTS

Samples for these tests were submitted in the form of standard briquettes used in cement testing. These briquettes were cut out of blocks about 1″ thick of the respective materials.

These tests were made in a standard tensile testing machine having a capacity of 4,000 lbs. The jaws employed corresponded in design with the standard shape used in testing cement briquettes.

SAMPLES TESTED AS RECEIVED

		Tensile strength, pounds per square inch
Class "A"	Specimen No. 1	2,000
	Specimen No. 2	940
	Specimen No. 3	1,090
	Specimen No. 4	1,010
Class "B"	Specimen No. 1	1,550
	Specimen No. 2	920
	Specimen No. 3	1,285
	Specimen No. 4	1,421
Class "C"	Specimen No. 1	2,230
	Specimen No. 2	1,985
	Specimen No. 3	2,478
	Specimen No. 4	2,918
Class "G"	Specimen No. 1	3,020
	Specimen No. 2	4,000
	Specimen No. 3	2,920
	Specimen No. 4	3,405
Class "G" (a)	Specimen No. 1	4,750
	Specimen No. 2	3,780
	Specimen No. 3	2,880
	Specimen No. 4	3,860

ARC TESTS

The following samples were submitted for tests:

Class "B"	Molded piece of irregular shape 1⅝"x2⅜"x¼" over all.
Class "C"	Molded block 4½"x2⅝"x2½".
Class "C" (a)	Molded block 5"x3"x¾".
Class "C" (b)	Disc 4½"x⅜".
Class "G"	Block 3"x1"x1".
Class "G" (a)	Block 2¾"x1¾"x⅝".

TESTS

(a) Sample held ¼" above the flame of the arc for one minute.

(b) Sample passed slowly through a part of the flame of the arc.

(c) Sample held in the flame of the arc for one minute.

(d) Sample ignited, when possible, and then held in the open air.

(e) Sample carbonized when possible, and held across the extinguished arc, carbons still hot, to re-establish arc.

(f) Same as test "e," except carbons were first allowed to cool.

RESULTS OF TESTS

Class "B"

Test	Result
a.	Became red hot and charred slightly.
b.	Charred, but did not catch fire.
c.	Became red hot and charred.
d.	Became red hot, would not burn.
e.	When carbonized was conducting.
f.	When carbonized was conducting.

Class "C"

Test	Result
a.	No noticeable effect.
b.	Fused quickly to a glass-like substance.
c.	Fused slowly.
d.	Would not burn.
e.	Non-combustible and non-conducting.
f.	Non-combustible and non-conducting.

2. Class "C" (a)

Test	Result
a.	No noticeable effect.
b.	Fused slowly.
c.	Fused slowly.
d.	Would not burn.
e.	Non-combustible and non-conducting.
f.	Non-combustible and non-conducting.

Class "C" (b)

Test	Result
a.	Charred slightly.
b.	Caught fire slowly.
c.	Caught fire and fused.
d.	Would not burn outside of arc.
e.	Fused portion was conducting.
f.	Fused portion was non-conducting.

Class "G"

Test	Result
a.	Caught fire slowly.
b.	Caught fire, but stopped on leaving arc.
c.	Caught fire and burned in air a little.
d.	Caught fire and burned in air a little.
e.	Charred and became conducting.
f.	Charred and became conducting.

Class "G" (a)

Test	Result
a.	Caught fire instantly.
b.	Caught fire and continued to burn.
c.	Caught fire and charred.
d.	Caught fire and burned for about 1 minute.
e.	Charred and became conducting.

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